Aircraft Maintenance

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by

DANIEL J. BRIMM, Jr. M.A., A.F.I.Ae.S.

Licensed Pilot; Licensed Airplane and Engine Mechanic; Instructor in Airplane Engines, New York City School of Aviation Trades. Formerly Test Pilot; Manager Marine Flying Service; Chief Engineer Ireland Aircraft, Inc.

and

H. EDWARD BOGGESS

Licensed Pilot; Licensed Airplane and Engine Mechanic; Instructor in Airplane Mechanics, New York City School of Aviation Trades. Formerly Ground School Instructor; Flight Mechanic Curtiss Flying Service; Co-pilot Roosevelt Flying Corporation.

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Professor Alexander Klemin
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FOREWORD

Many books have been written for "ground school" courses, but this is the first I have seen which covers the work of an aviation mechanic on a strictly trade basis. It not only lists the various jobs the mechanic should do, but tells him in detail how to do them and, furthermore, supplies the student with a substantial fund of related technical information which should raise him well above the level of the purely manual worker.

I feel that this book takes care of a need which is growing more and more acute, and that it will be of great benefit to the individuals who wish to become airplane mechanics, to those who already are, and to the industry in general.

Clyde Pangborn

PREFACE TO REVISED EDITION

In the preparation of this revised edition of "AIRPLANE AND ENGINE MAINTENANCE" the authors have endeavored to incorporate valuable suggestions and comments from many users of the first edition.

A number of these readers requested more engine material. Accordingly, an entire book ("AIRCRAFT ENGINE MAINTENANCE") on that subject has been published and may be obtained from any of the sources supplying this volume.

Another request was for more information on metal work. This has likewise been complied with by using most of the hundred-odd pages formerly devoted to engines for a more complete treatise on metal construction.

The remainder of the available space has been used for a discussion of basic hydraulic systems and mechanisms, another subject requested.

A list of the Army-Navy ("AN") specifications has been added, because of their general acceptance by the majority of aircraft manufacturers. The index has been greatly amplified. All-in-all, it is believed that this edition will prove to be even more valuable for home and school work than its predecessor.

D. J. Brimm, Jr.

H. E. Boggess.

PREFACE TO FIRST EDITION

This book has been prepared with three purposes in mind: It is intended to serve as a home study course for the student mechanic; as an aid to the instructor and student in secondary schools, either public or private, training aviation mechanics; and as a reference and handbook for the licensed mechanic.

For the beginner there are practice jobs and instructions in the use of tools which, if properly carried out, should equip him for any ordinary work he might be called on to do in the trade. For the teacher, detailed instruction sheets and related information are supplied which, it is hoped, will be of service in laying out his courses. The instruction sheets have been thoroughly tried out in shop classes and made workable by actual tests. For the finished mechanic, tables and other reference data are included.

While, in general, the N. A. C. A. nomenclature is employed, trade terms and mechanics' colloquialisms are also used, both to familiarize the student with the language of the industry and to avoid any appearance of too much technicality. Examples of this are the use of "beam" as synonymous with "spar", "dural" for duralumin or aluminum alloy, "ship" for airplane, "motor" for engine, etc. However, no expressions are used which are not generally accepted in the trade.

The authors are extremely grateful to the various manufacturers and dealers who have cooperated so generously in supplying illustrations and data. Acknowledgment of the source of such material is either given directly with it or contained in the accompanying text.

To the Advisory Editor of the publishers, Professor Alexander Klemin, Daniel Guggenheim School of Aeronautics, New York University, the authors extend their thanks for assistance and suggestions.

Naturally, the regulations of the Civil Aeronautics Authority regarding repairs and other practices have been followed strictly where they apply.

Daniel J. Brimm, Jr.

H. Edward Boggess

INTRODUCTION

It is impossible to over-emphasize the importance of a thorough knowledge of the duties, requirements and responsibilities of a mechanic. In addition to learning how to master his craft the mechanic must learn the Civil Aeronautic Authority regulations which pertain to his work. Bulletins containing the information may be obtained from the Government Publishing Bureau, Washington, D.C.

The following mechanic rating regulations are contained in the Civil Air Regulations Bulletin No. 24:

"Mechanic ratings will be as follows:
(a) Aircraft Mechanic Rating.
(b) Aircraft Engine Mechanic Rating.

"MINIMUM REQUIREMENTS.- To be eligible for a mechanic competency rating, an applicant shall comply with the following minimum requirements prescribed for the particular rating sought.

"Aircraft Mechanic Rating.- To be eligible for an aircraft mechanic rating, an applicant shall comply with the following minimum requirements.

"Age.- Applicant shall be at least 18 years of age.

"Character.- Applicant shall be of good moral character.

"Citizenship.- Applicant may be a citizen of any nationality.

"Education.- Applicant shall be able to read, speak, write and understand the English language.

"Aeronautical Knowledge.- Applicant shall have theoretical and practical knowledge of aircraft structure and rigging, including the control systems, shall know how to properly inspect, maintain, repair and overhaul the same, and shall be familiar with the provisions of CAR 00, 01, 02, 04, 15, 18 and 24.

"Aeronautical Experience.- Applicant shall have had at least one year of practical experience in the construction, maintenance, or repair of aircraft.

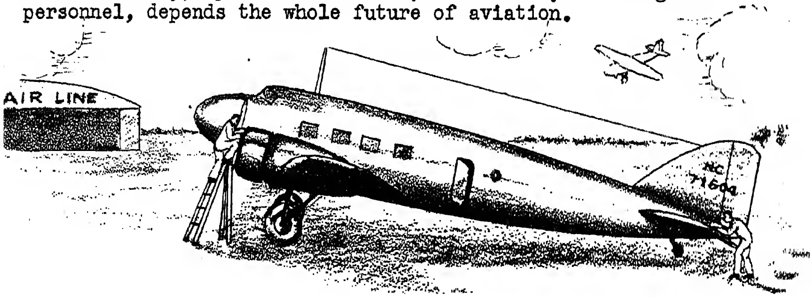
"Aeronautical Skill.- Applicant shall satisfactorily demonstrate, by means of written, oral and practical tests, his ability with respect to the subject matters prescribed in CAR 24.104."

The most important characteristic of a good mechanic is a feeling of responsibility. This will mean a refusal to do slipshod work, to cover up mistakes, to take anything for granted as to the condition of the ships in his care, and will result in his steady advancement.

His duties may have a rather wide scope, depending on the type of organization with which he is associated. If he is employed by a large airline, he may be assigned to just one particular part of the ship, which he is expected to inspect or repair, as the case may be, whenever an airliner lands or at specified intervals. If, on the other hand, he is working for a smaller outfit, such as an air taxi concern, a flying school, a sales agency or the like, he may have almost any kind of a job, from washing down the ships or cleaning the hangar to doing a top overhaul on the engine or splicing a wing beam or recovering a fuselage. As a matter of fact, to be a first class, all around airplane and engine mechanic, one must be something of an expert at a number of different trades. He must be a good wood-worker, a good metal-worker, a good fabric and upholstery man, a good painter, particularly as regards spray painting, something of a machinist, a tinsmith, and if he is a good welder it is a great asset. On top of this, he naturally must be an expert on aircraft engines. There are, of course, not many who meet all of these qualifications, but to hold down any sort of worthwhile job, the candidate must be very capable in at least several of the fields mentioned and have some knowledge of the others.

In a factory such a wide diversity of skills is not necessary. But since there is more specialization in the factory, the worker must be correspondingly more expert in a particular job, and a knowledge outside of that is a decided asset if he expects much in the way of promotion. The factories probably offer more in the way of a real future than field work. Though they may be less interesting and romantic, there is much less likelihood of layoffs, due to the fact that their business is not seasonal, as are flying operations, particularly in the case of the smaller operating companies, and more than one ordinary mechanic has wound up as factory superintendent, chief engineer, or in some other executive capacity.

While aviation has had and will probably always have more glamour than any other business, it should be considered, after all, as a business by anyone considering making it his life work, for glamour does not pay grocery bills. Considered in its proper light, it offers as much opportunity as anything else, if not more. The same rules of success - thoroughness, dependability, speed and honesty - apply as in any other business, only more so. And conversely, upon the efficiency and ability of the ground personnel, depends the whole future of aviation.



READING DRAWINGS

It is not the purpose of the following instructions to give, in any way, a course in the reading of plans and blueprints. However, there are certain standard practices in making drawings with which every mechanic should be familiar.

A mechanical drawing is nothing more or less than a set of instructions to the mechanic, in which symbols and dimensions take the place of a great deal of explanation. It has been said that "a picture takes the place of ten thousand words."

To begin with, the principle of projections should be understood. In the customary method, the view shown on the right side of another view is what would be seen if the observer moved around to the right of the object. Fig. I illustrates this.

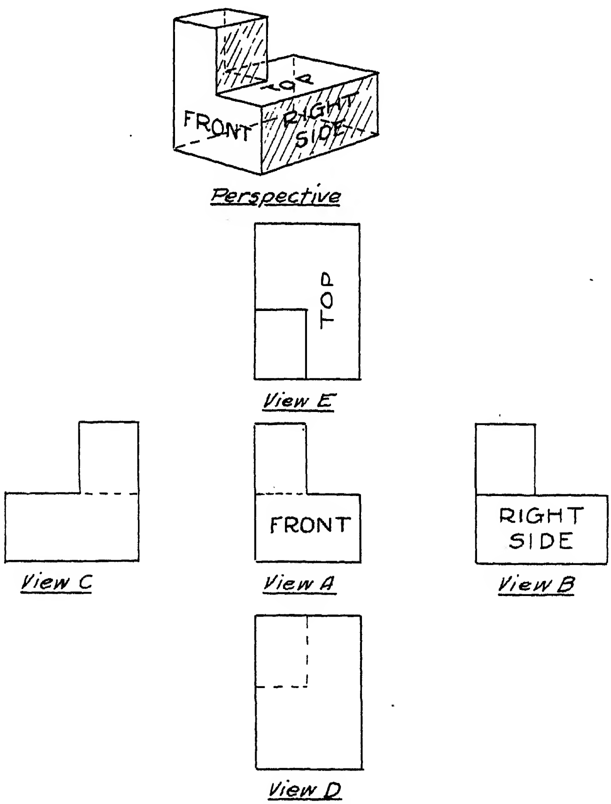


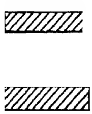
FIG. I

READING DRAWINGS
(continued)

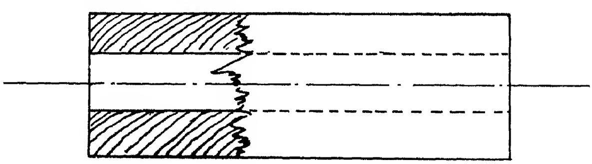
The sketch labelled "Perspective" is the way the object actually appears to an observer stationed in front of and above it. (The object is simply a block of irregular shape.) The views below marked A, B, C, D, E, are respectively, the front, technically known as the front elevation, the right side or side elevation, the left side, also called the side elevation, the bottom, called the (bottom) plan and the top, called the (top) plan, drawn by the principles of mechanical drawing, in which an object is drawn not as it appears but as it actually is - in other words, the dimensions of the drawing are the actual dimensions of the object, reduced, if necessary, in proportion.

Somewhere on the drawing it is customary, though not essential, to mention the amount each dimension has been reduced, if any. This is called the "scale" of the drawing. For example, if there is a notation "Scale - Full Size" it means that if a dimension is given as one inch (1") on the drawing, it actually measures an inch. If, however, the notation reads "Scale - 1" = 1'" or simply "1" = 1'" it means that an inch on the drawing is equal to a foot on the finished part, or, in other words, the drawing is 1/12 actual size.

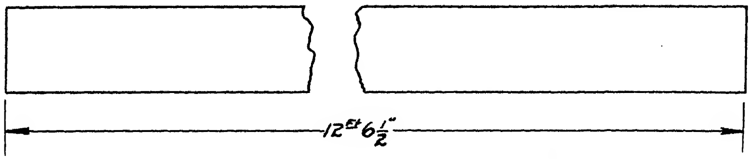
Various types of lines are used for various purposes. A solid line ———————————— represents an outline or corner which is visible to the observer in that view of the object. A dotted or dashed line - - - - - - - - - - - - - - - - indicates a corner or surface on the other side or the inside of the object, and hence not visible to the observer in that particular view. A line like this ————·————·———·—— is used for the centerline, often marked ℄, and one like this ————··————··———— indicates something which is not a part of the drawing but the relative position of which needs to be indicated. For example, the longerons in the sketch on the sheet, "Fuselage Fairings". A fine broken line such as this ———— ———— ———— is simply an extension line indicating the point to which a dimension is given. If the section of a piece needs to be shown, the portion made visible by the cut is "cross-hatched". For example, if a hollow cylinder were shown with part of it cut away, it would look like this



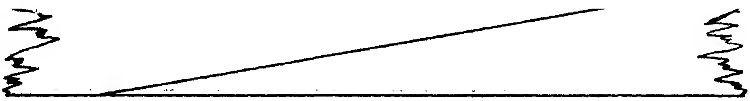
or if it were made of wood, it might be shown like this



If it is desired to show the dimensions of a long piece which could not be shown on the sheet in its entire length, it may be broken like this

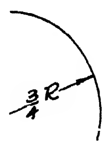


or, if the portion not shown is dimensioned elsewhere, it may simply be broken off, as in the case of a beam splice, where it is desired to show only the splice, such as this

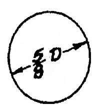


The jagged break is commonly used for wood and the wavy break for other material.

Since dimensions in this country are usually in inches, unless otherwise specified, the inch marks (") are omitted. Eleven and seven-sixteenths inches would be written 11 7/16. The letter "R" means the radius of the arc, and may be written as shown in sketch, or the "R" may be left out and the dimensions alone inserted. Or if there isn't room to insert the dimensions, as shown, it may be indicated thus



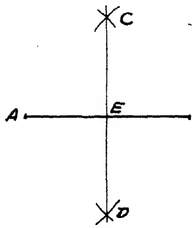
The diameter of a hole is usually indicated as shown in sketch, if the hole is more than 1/2" in diameter, though sometimes the "D" is omitted. If the hole is smaller, its size is usually shown by the drill designated as



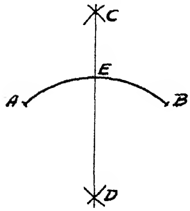
If the piece is U-shaped and it is desired to have holes on each side of the U in line with each other, the note should read

With these instructions and a little common sense, the mechanic should be able to interpret any ordinary drawing.

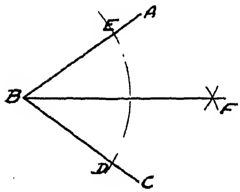
SIMPLE LAYOUT PROBLEMS



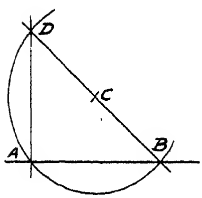
PROBLEM 1: TO BISECT A LINE AB.
With ends of line, A and B as centers, and a radius of more than half of AB, draw arcs intersecting at C and D. Draw CD and E is the center of the line AB. Also, CD is perpendicular to AB.



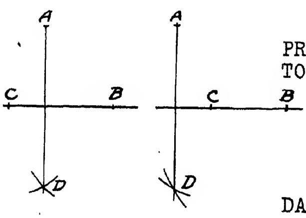
PROBLEM 2: TO BISECT AN ARC, AB.
With A and B as centers, and a radius of more than half of AB, draw arcs intersecting at C and D. Draw CD. E is the center point of the arc AB.



PROBLEM 3: TO BISECT ANY ANGLE, ABC.
With B as center and any convenient radius, draw arc ED. With E and D as centers and a radius of more than half of ED, draw arcs intersecting at F. Draw FB. Angle FBA equals angle FBC.

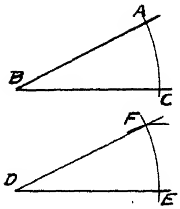


PROBLEM 4: TO ERECT AT A GIVEN POINT A, A LINE PERPENDICULAR TO LINE AB.
With any point such as C as center, and radius CA, draw arc BAD. Through B and C draw line cutting arc at D. Draw DA, which is perpendicular to AB.

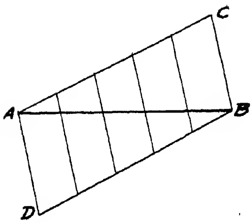


PROBLEM 5: TO DRAW A LINE AT RIGHT ANGLES TO A GIVEN LINE, FROM A GIVEN POINT A.
Take any two points on the line, such as B and C. With B as a center and radius BA, draw an arc. With C as a center and radius CA draw another arc. These arcs intersect at D. Draw DA. DA is perpendicular to original line.

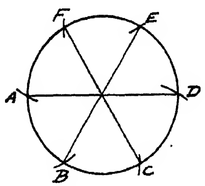
SIMPLE LAYOUT PROBLEMS
(continued)



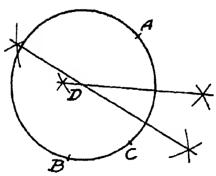
PROBLEM 6: TO DRAW AN ANGLE EQUAL TO ANOTHER ANGLE, ABC.
With B as a center, draw an arc, AC. With D as center, using the same radius, draw the arc FE. With E as center and radius equal to CA, draw an arc intersecting the arc FE. Draw FD. The angle FDE is equal to the angle ABC.



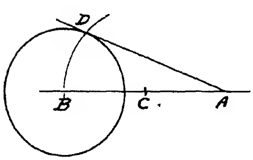
PROBLEM 7: TO DIVIDE A GIVEN LINE AB INTO ANY NUMBER OF EQUAL PARTS, SAY FIVE.
Through A draw line AC at any convenient angle. At B draw line BD, so that angle ABD equals angle CAB. (See Problem 6). Lay off five points at equal distances apart, beginning at A, on line AC. Do the same, beginning at B on line BD. Connect points as shown. The connecting lines divide AB into five equal parts.



PROBLEM 8: TO DIVIDE THE CIRCUMFERENCE OF A CIRCLE INTO SIX EQUAL PARTS.
Using the radius of the circle, begin at any point on the circumference, such as A, and draw arc, cutting circumference at B. Using B as a center draw arc cutting circumference at C, and so on around. If the points are connected as shown, the angles formed at the center will of course be 60° each.



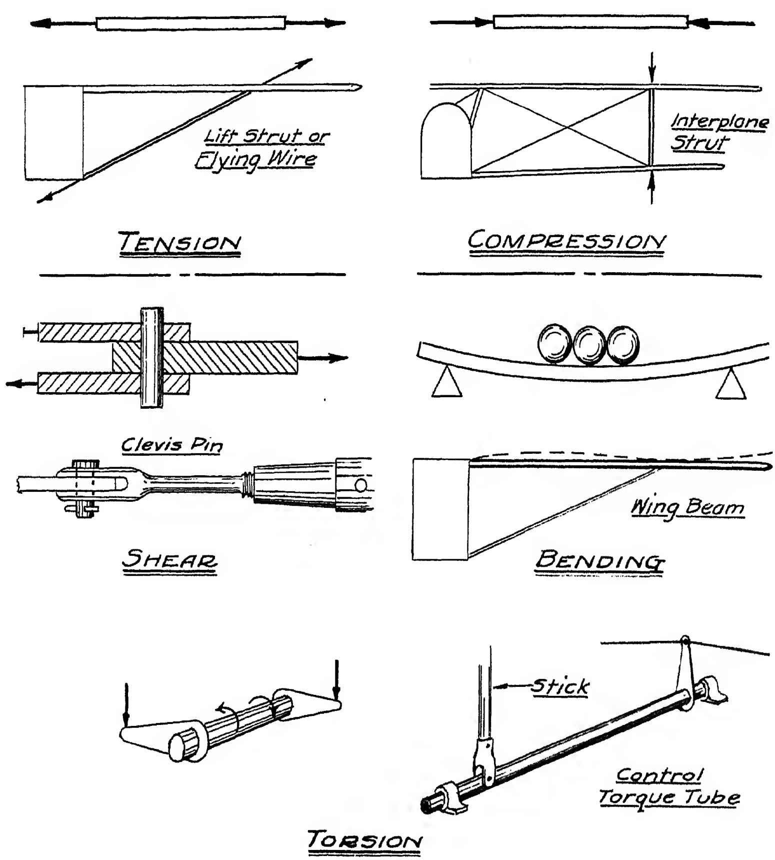
PROBLEM 9: TO FIND THE CENTER OF A GIVEN CIRCLE.
Bisect any two arcs on the circumference, such as AB and AC. The point where the bisecting lines cross each other, D, is the center of the circle.



PROBLEM 10: TO FIND THE EXACT POINT OF TANGENCY WHEN A TANGENT TO A CIRCLE IS DRAWN FROM A GIVEN POINT A.
Connect A with center of circle, B. Bisect AB as in Problem 1, finding point C. With C as a center and CB as a radius, draw arc cutting the circumference at D, which is the point of tangency of line AD.

THE FIVE STRESSES

There are five types of stresses to which a member may be subjected: Tension, Compression, Shear, Bending, and Torsion. Stress is a force tending to distort the material, or change its dimensions. Strain is the distortion, or change. Whenever there is a stress, however slight, there is also a strain. If a piece of material is stressed only up to a certain point, or to put it in somewhat simpler terms, if the material is made to carry only a certain load and the load is removed, the material will resume its original shape and dimensions. If, however, the load is increased beyond that point and then removed, the material will not come back. The point at which an increase in the stress will result in permanent distortion of the material is called the Elastic Limit or Yield Point. Stress is always described in pounds per square inch, in our system of measurements. The illustrations below make the action of the various types of stresses much more understandable than a great deal of explanation.



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AIRCRAFT WOODWORK

Courtesy Fairchild Aircraft Corporation

THE CLARK-FAIRCHILD DURAMOLD AIRPLANE

INTRODUCTION

While the modern tendency is undeniably toward metal aircraft, it will be a long, long time before wood is discarded entirely as a structural material, particularly on small ships. There are two important reasons for this, namely, cost and weight. Until the production of small airplanes exceeds by many times the present output, wooden beams will be much cheaper than metal ones, because the fabrication of a metal beam is a laborious operation if done by hand, and if stamped out or otherwise made by machinery, the cost of the dies for the limited quantities now needed is prohibitive. Designs change every year and it is next to impossible to use parts built for one ship in another, even though the variation in the model may be slight. Furthermore, it is very difficult to use metal in a small structure so as to take advantage of its full strength, the result being that a wooden structure equally strong will almost always weigh less than the metal.

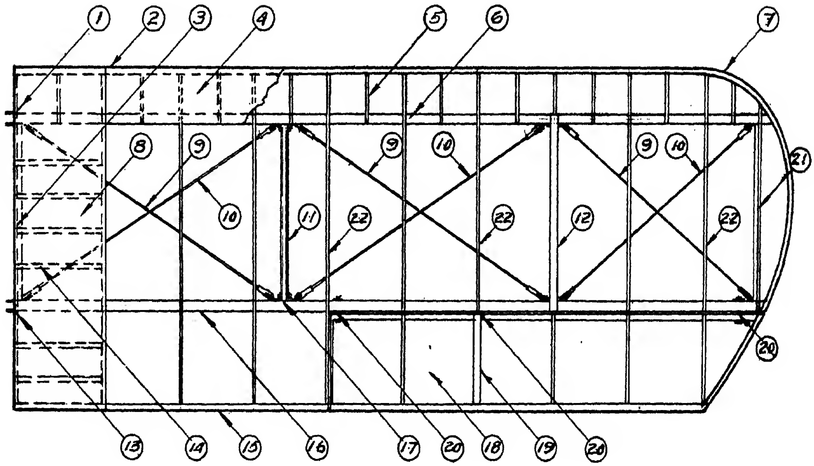
While the foregoing applies particularly to beams, the same is true to a lesser extent in regard to ribs. Many of the medium size ships now use metal ribs, but some still use wood, and the majority of the two-place types find wood a more economical material. Hence it is safe to say that it will be quite a few years before wings are a hundred per cent metal.

This means that not only for the period during which wood is used on the new models will it be necessary for the airplane mechanic to be able to repair such structures, but for several years thereafter, until all of the ships using wooden construction have been discarded.

There are many advantages other than those mentioned in the use of wood. Repairs can be made by any licensed mechanic, subject to inspection by a Civil Aeronautics Authority Inspector, ribs can be rebuilt, beams can be spliced, without waiting for parts to come from the factory. In the case of metal wings, it is often difficult, if not impossible, to make any field repairs, and new parts have to be ordered, with consequent delay in getting the ship back into service again. And always remember that a ship on the ground produces no revenue, but on the contrary is "eating its head off" in hangar rent. A repair on a wooden rib is a comparatively simple matter, and usually does not call for much in the way of fabric repairs. A metal rib always has to be completely replaced with a new one from the factory, which means not only the time lost in securing the rib, but also a much bigger opening in the cover, assuming that the cover is cloth. If the wing is metal covered then the job begins to assume really serious proportions, often calling for a complete new wing.

The portion of this book devoted to woodwork covers all the types of work that a mechanic is likely to be called on to do, and if he is capable in those jobs which are taken up in the following pages, he should be able to handle any additional problem that may arise.

WING NOMENCLATURE



1. Front wing hinge fitting	12. Compression rib
2. Leading edge	13. Rear wing hinge fitting
3. Butt rib	14. Sidewalk reinforcements
4. Nose fairing	15. Trailing edge
5. Nose ribs	16. Rear beam or spar
6. Front beam or spar	17. Drag wire fitting
7. Wing tip bow	18. Aileron
8. Sidewalk	19. Aileron horn rib
9. Drag wire	20. Aileron hinges
10. Anti-drag wires	21. Tip ribs
11. Drag strut or compression tube	22. Former or standard ribs

Notes:

The drawing shows the plan view of a lower right wing with the covering removed.

Sometimes the ailerons are on the upper wings only, sometimes on the lower only, and sometimes on both.

The sidewalk is never on the upper wing.

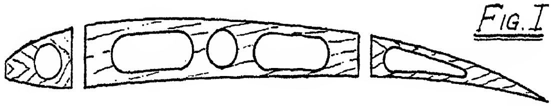
The expression "drag truss" means the front and rear beams, the compression ribs and members, the drag and anti-drag wires only.

The standard ribs, nose ribs, aileron, tip bow etc., are not included as a part of the drag truss.

THE EARLY TYPE WEB RIB

In many of the early type airplanes the form ribs were made with a solid web cut to the shape of the airfoil. The web was made of thin sheet spruce, usually about 3/16" thick with several large holes in the web to reduce weight. These ribs were made in three sections: the nose, the center, and the trailing section, in order to allow space for the front and rear beams. See Fig. I.

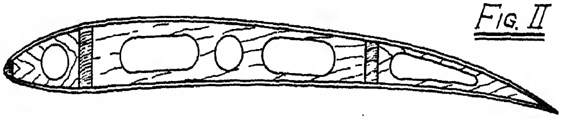
FIG. I



Sections of a Web

To hold the three sections together and to fasten the rib to the beam, a rabbeted capstrip was glued and nailed along the top and bottom of the web. This capstrip, usually about 1/2" wide, also served to provide a larger bearing surface for the fabric, Fig. II.

FIG. II



Web Rib

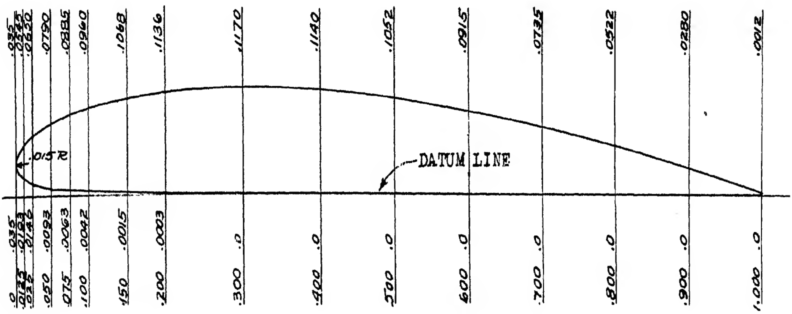
To construct a rib of this type was a slow process and much hand labor was needed, since in the majority of cases the ribs had to be assembled one at a time on the beams. The cost of labor, together with the cost of the materials used, made this an expensive type of construction.

HOW TO LAY OUT A WING CURVE OR PROFILE

The upper and lower camber or curvature oı a section is laid out from abscissae and ordinates supplied l wind or aerodynamic laboratory which tests the airfoil. y are aıway given in decimal parts of the chord. Thus, a rib o any size may be laid out in proper proportions. The abscissae measured from the nose or leading edge and the ordinates from a tum line, which is usually a line touching the bottom curve at or more points but in the case of double-cambered sections may from the nose to the tail or trailing edge.

To obtain the proper dimensions in inches for laying out the section to scale, the abscissae and ordinates must, of course, be multiplied by the chord length in inches.

The airfoil which will be used below is ark Y, an lent section for all around use. The chord chosen is five feet or 60".



The lowest row of figures indicates the distance from the nose in decimal parts of the chord, the next row is the height of the bottom curve from the datum line and the top row the height of the top curve. It will be noted that from .3 on back the bottom ordinate is zero, indicating that the bottom of the section is flat. The next step is to lay out a table of ordinates for convenience. The procedure is clearly indicated on the following page.

Secure a sheet of tough drawing paper and using a hard pencil, sharpened to a keen chisel point, and an accurate straight edge, draw the datum line. With a scale divided into hundredths of an inch, lay out the abscissae (second column) along the line. If such a scale is not available, a table of decimal equivalents must be used and the dimensions converted to sixty-fourths.

Square up a line accurately from each point and set off the ordinates (columns 4 and 6). It is desirable to use a needle with the eye end forced into a small piece of wood to mark the points. A small circle should be drawn around each with a pencil to make them more easily located.

HOW TO LAY OUT A WING CURVE OR PROFILE

Distance from nose	Times 60"	Bottom Camber	Times 60"	Top Camber	Times 60"
.0	.0	.035	2.10"	.035	2.10"
.0125	0.75"	.0193	1.16"	.0545	3.27"
.025	1.50"	.0146	.88"	.0650	3.90"
.050	3.00"	.0093	.56"	.0790	4.74"
.075	4.50"	.0063	.38"	.0885	5.31"
.100	6.00"	.0042	.25"	.0960	5.76"
.150	9.00"	.0015	.09"	.1068	6.41"
.200	12.00"	.0003	.02"	.1136	6.82"
.300	18.00"	.0	.0	.1170	7.02"
.400	24.00"	.0	.0	.1140	6.84"
.500	30.00"	.0	.0	.1052	6.31"
.600	36.00"	.0	.0	.0915	5.49"
.700	42.00"	.0	.0	.0735	4.41"
.800	48.00"	.0	.0	.0522	3.13"
.900	54.00"	.0	.0	.0280	1.68"
1.000	60.00"	.0	.0	.0012	.07"
R- .015	.9"				

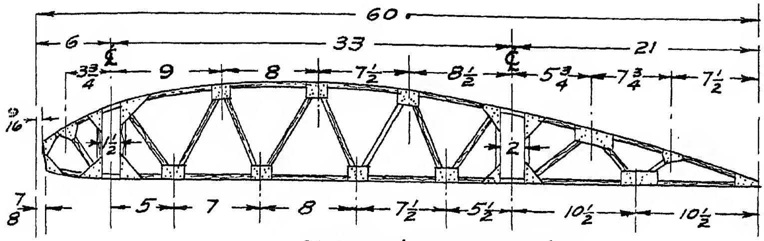
Bend a smooth, flexible piece of wood or celluloid so that it lies with one edge directly through the points. It may be held in position by fine brads, weights, or an assistant. With a sharp pencil draw a line through the points of top or bottom curve, then through the other set of points. With a compass set to the proper radius (.9" in this case) draw the nose radius just tangent to the curve.

It will be noted that the instructions above call for the use of a strip of flexible material (called a "spline" or "batten") in laying out the curve. It is possible to get long sweeping curves made of wood or celluloid called "ship curves" which will usually fit the lines to be drawn and there is always a temptation, if they are available, to use them instead of a spline. This should never be done, however, as it is practically impossible to get an absolutely "fair" or smooth curve, with no irregularities, unless a spline is used first. If it is desired to make the line heavier, the ship curves may be used afterwards.

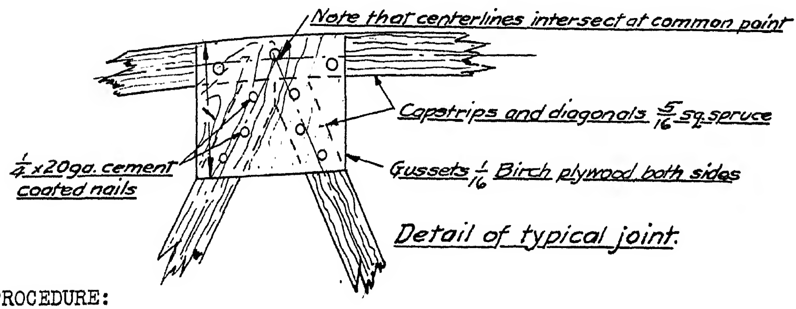
Bear in mind that accuracy in a wing section is of utmost importance, and it is obvious that the finished wing cannot be accurate unless the original layout is extremely exact.

HOW TO LAY OUT A WING RIB

Note: The airfoil section has already been laid out.
The drawing of the rib is supplied by the designer as shown below.



Glue all joints with casein glue



PROCEDURE:

1. Lay out beam locations with extreme accuracy and draw center lines of beams perpendicular to datum line, unless otherwise specified.

2. Lay out position of joints and draw center lines perpendicular to datum line.

3. At each station point or joint, measure 5/32" <u>in</u> from contour and mark point.

4. Connect these points by fine lines. These are the center lines of diagonal members, also known as web or truss members.

5. Draw parallel lines 5/32" each side of these center lines. These will show the outside of the diagonals. (Note that at the beam points the dimensions are given to the <u>inside</u> of the member. The outside is, of course, 5/16" from the dimension given.)

6. Lay out gussets from detail drawing. Make all corner gussets 1-1/2" wide, as shown at front beam.

The layout is now complete, ready for the construction of the jig.

HOW TO MAKE A RIB JIG

MATERIALS: Base board, 3/4" x 8" x 72"; supply of pins; fine sandpaper; rib layout drawing; approximately 2 sq. ft. 1/4" pine; 3/4" brad; casein glue; short length of capstrip 5/16" square.

TOOLS: Smooth plane, steel rule, batten or celluloid bending strip, sharp pencil, back saw, wood chisel, hammer, glue bottle.

PROCEDURE:

1. Surface one face of the board. Caution: Make sure that this surface is smooth and free from any warp or wind so that the ribs made on this jig will be true.

2. Sand the surface thoroughly.

3. Tack the rib layout drawing on the finished surface so that the rib is centered, leaving approximately an even margin on all sides.

4. Transfer the capstrip location to the board by outlining with pins the outside and inside of both capstrips (note drawing).

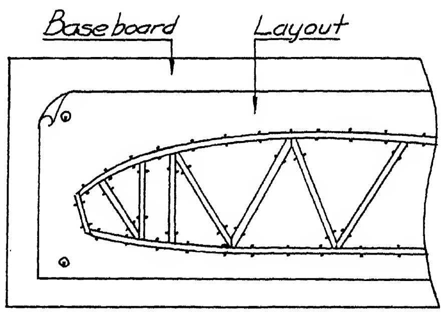
5. Transfer the locations of the bracing or web members to the board by sticking pins through the drawing on both sides and at each end of every member.

6. Remove the drawing.

7. Using the drawing as a guide to avoid error, completely fill in the camber lines by marking around a batten bent so that it touches all the pin holes in the camber line, as was done in making the drawing.

8. Fill in the diagonals by connecting the proper pin holes.

9. Check the layout with the drawing.



Dots show pin locations

The accuracy of the rib will depend upon the accuracy of the rib jig, so inspect your layout with this in mind and answer the following questions:

1. Are all of the capstrip measurements correct?
2. Are all of the web member widths correct?
3. Are the spar openings the correct size?
4. Is the trailing edge joint made correctly?

HOW TO MAKE A RIB JIG
(continued)

BLOCKING IN:

10. Saw the 1/4" material into blocks measuring about 1" x 2".

11. Mix a small quantity of casein glue.

12. Fit, glue and nail the blocks on the board in such a manner as to hold the web members and capstrips in place as per layout.

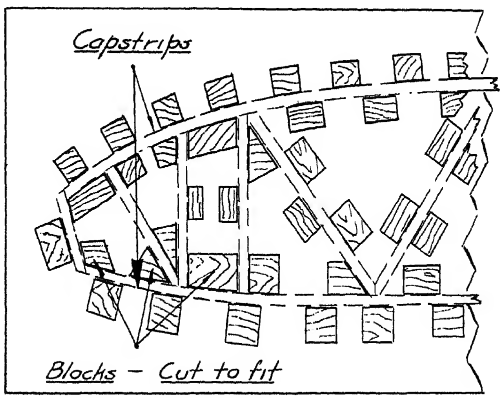
Note: In fitting the blocks to the jig board layout, it must be remembered that the function of these blocks is to hold the members in the correct position. With this in mind the blocks will be cut to any suitable size and shape, in general spacing them about 1" to 2" apart, as shown on the drawing below. Before these blocks are finally nailed in place, each set should be tested with a sample capstrip to make sure that they are the correct distance apart. The capstrip should be a snug fit.

13. Check the jig board and blocks with the layout drawing.

14. Sand the jig thoroughly.

15. Varnish with a good grade of spar varnish.

Note: Where a large number of ribs are to be made on one jig board it is best to paint the jig board with hot paraffin, as this prevents the glue from the gusset plates sticking to the board.



RIB JIG = NOSE SECTION

Where the curve of the rib is great, or where the diagonals are close together, it is sometimes more desirable to use one large, shaped plate instead of several small blocks, for when the blocks are too small they have a tendency to split. If this is done it may be remembered that the plate should be thinner than the capstrip, to allow the gusset plates to be nailed in place. For small ribs, control surface ribs, etc., it is more practical to make the entire jig by the plate method. When the plate method is used, holes are sometimes drilled at the truss intersections so that the finished rib may be pushed out from the bottom with a small stick or pencil.

HOW TO BUILD A TRUSSED RIB

MATERIAL: 3 Spruce strips dressed to 5/16" x 5/16" x 8'; 1 sq. ft. 3/64" - 3 ply birch or mahogany plywood; 1/4" - 20 gauge aircraft nails; casein glue; sandpaper.

TOOLS: Jack plane, block plane, 1" wood chisel, back saw, bench hook, tack hammer, steel scale.

PROCEDURE:

1. Make sure that all spruce strips are exactly 5/16" square.

2. Place one spruce strip in the jig for the top capstrip, by starting it in the leading edge and gradually bending it into the jig.

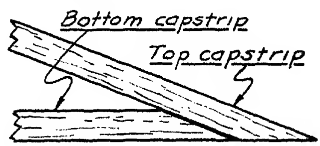
Note: If a good grade of spruce is used it should be unnecessary to soak the strips before bending. If a substitute for spruce is used, it will probably be better to soak it in warm water for 30 minutes before trying to bend it.

3. Place the second strip in position for the bottom capstrip.

4. Cut the trailing edge joint as shown in Fig. I.

5. Cut a short section from the third strip to form the leading edge joints as shown on Page 9.

6. Cut and fit the truss members, making sure that each joint fits correctly.



TRAILING EDGE JOINT

7. Use the wood chisel to make sure that each joint is flush. This is necessary to provide a true bearing surface for the gusset plate.

8. Mix a small quantity of casein glue.

9. Cut the gusset plates from the plywood to cover each joint. Detail of gusset plates is shown on Page 7.

10. Scrape the reverse side of the gusset plates with a chisel, apply the glue and nail in place, using at least one nail in each member and spacing the nails not closer than 1/4" apart.

11. Remove the rib from the jig and check the joints on the opposite side to make sure they are flush.

12. Glue and nail the gusset plates on the reverse side of the rib and sand thoroughly.

Note: No portion of any gusset plate should extend above the capstrip or interfere with the clearance at the spar openings.

TESTING WING RIBS

It is not necessary for a mechanic to run what are called "static tests" on wing ribs, but it is well for him to have some idea how it is done. These tests are required by the Civil Aeronautics Authority before the ship, in which the ribs are to be used is given a license or Approved Type Certificate. The tests consist of loading sand or other weights on the rib until it breaks. If it holds without breaking a load equivalent to that portion of the total weight of the airplane which it will have to carry, it is considered satisfactory. Otherwise, it must be strengthened where necessary.

There are a number of ways of applying the test load. Some use sand or shot, some a system of levers, and some a combination of the two. The simplest type is shown in Fig. II.

Before testing, of course, the load must be worked out and distributed properly along the chord. This is done by taking the wing loading in lbs. per sq. ft. on the wing and multiplying it by the area supported by one rib.

Example: Wing loading 11 lbs./sq. ft.
Chord 5 ft. Rib spacing 15" or 1.25 ft.
Area supported by 1 rib = 5 x 1.25 = 6.25 sq. ft.
11 x 6.25 = 68.75 lbs. For the sake of simplicity, call it 69 lbs.

Next, a line is drawn to scale, corresponding to the chord, and a triangle erected on it with an area in square inches equivalent to the load in lbs.

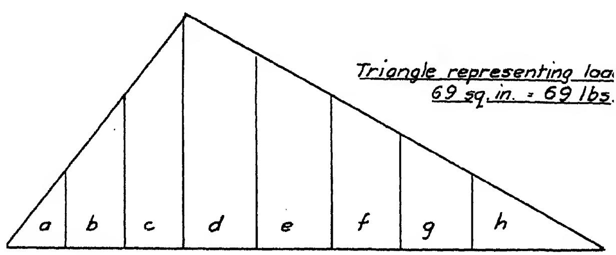


FIG. I

The area of each section, such as a, b, c, etc. is figured and since the triangle is laid out so that a square inch is equivalent to a pound, the area of the section in square inches gives the load in pounds.

TESTING WING RIBS
(continued)

Eight bags or buckets are now loaded with the proper weights of shot or sand and the bags or buckets hung on the rib, in locations corresponding to the centers of gravity of each of the sections (a, b, c, etc) in Fig. I. Small blocks are placed under the cords holding the bags to distribute the loads and prevent cutting. The loads are increased by the addition of more shot proportionately divided among the bags until the rib breaks. Then the total weight carried without breakage is divided by the original load and the quotient is the "Load Factor", or what is commonly called the "factor of safety", though the latter term is incorrect.

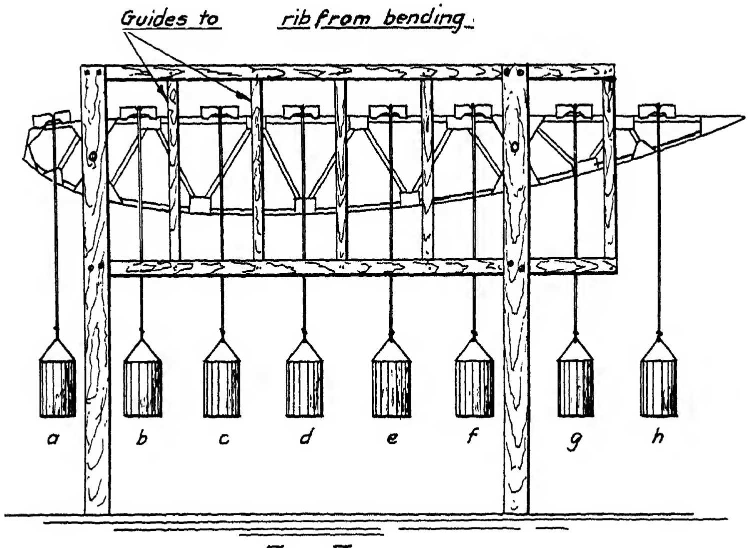


Fig. II

For example, if one of the members of the rib broke when the total load amounted to 435 lbs., the load factor would be 435/69 = 6.3 If this were high enough to meet the requirements specified by the Civil Aeronautics Regulations for the particular type of ship, the rib would be satisfactory. If not, the member that broke would be increased in size and a new test run until some other member failed. In this way, eventually a rib would be developed which met the strength requirements and yet was not any heavier than necessary.

SPLICING WOOD RIBS

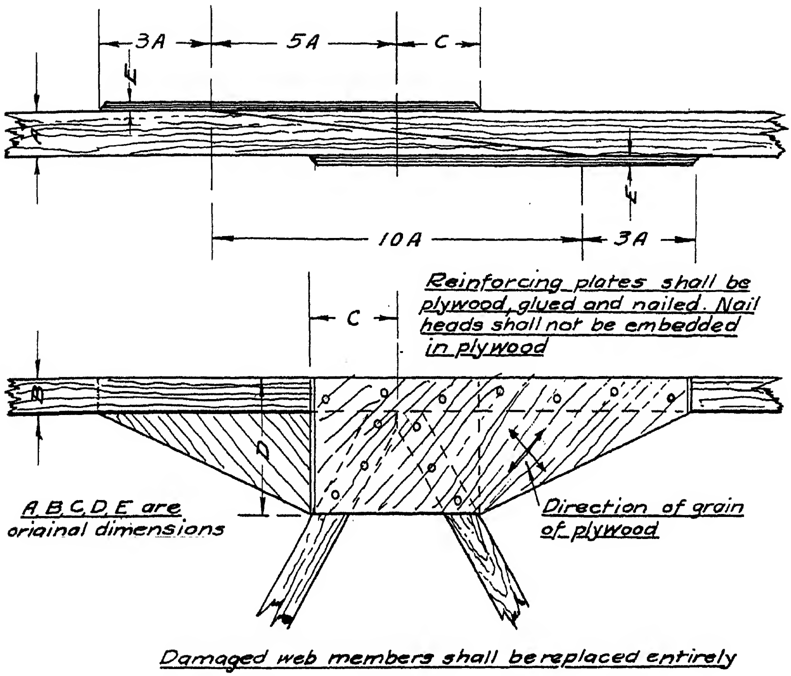


FIG. I. TYPICAL RIB SPLICE AT JOINT

Figures I and II illustrate the approved method of repairing wood ribs. The Civil Aeronautics Authority gives the following regulations governing wood rib repair:

"Cap strips shall be replaced entirely or repaired at the spars or at a joint in the rib.

"Damaged web members shall be replaced.

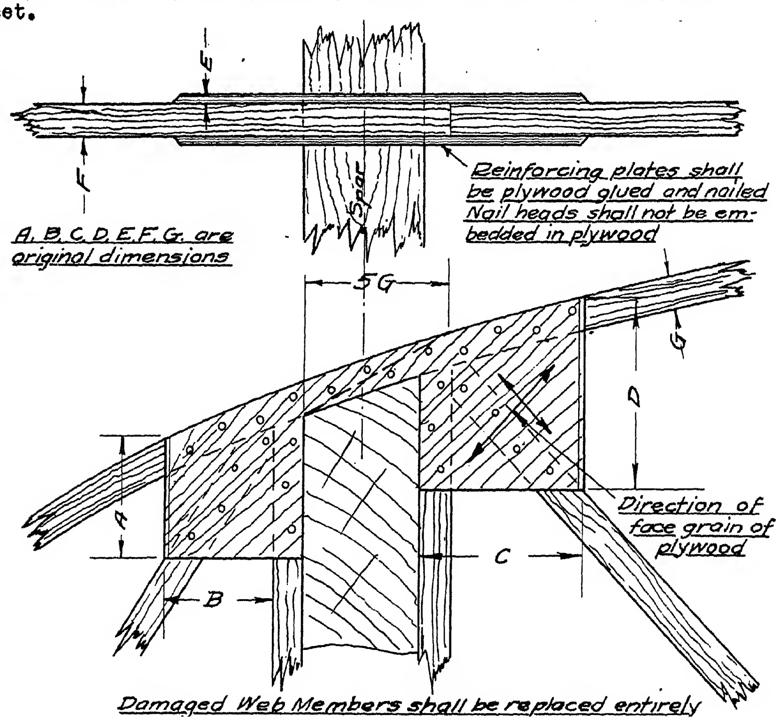
"Complete ribs shall be made from a manufacturers approved drawing or from a drawing made by the repair agency and certified by the manufacturer as correct, except that the original rib may be used as a pattern for making the new rib if it is not too seriously damaged to permit comparison. The drawing, if used, shall be retained by the repair agency for use by the Bureau Inspector in making the inspection."

The foregoing paragraphs are from the Civil Air Regulation bulletin number 18. Fig. I illustrates the proper method of making

SPLICING WOOD RIBS
(continued)

a splice at a joint. In driving the nails, a heavy piece of metal should be held against the rib to prevent knocking it out of line. After the nails have been driven, the joints should be clamped up tight with small C-clamps, with blocks of wood between the clamp and the rib to prevent damage to the latter, and left over night to dry. The reason for not driving the nails so far that the heads become embedded in the plywood plates is that the heads will crush the outer fibers of the reinforcing plates and weaken them. In addition, the heads of the nails may come off, thus spoiling any clamping effect they might have had. By "original dimensions" is meant the dimensions of the capstrip and gussets before the repair was made.

If web members, or diagonals, are broken, they may not be repaired, but must be replaced completely, of course with other members of the same size as the original. In doing this job, great care should be taken in removing the old gussets, so as not to pull off pieces of the capstrip or otherwise damage the rest of the rib. When the new parts are put in, new gussets will have to be put on with glue and nails, using C-clamps until the glue has set.



WOODS USED IN AIRPLANE CONSTRUCTION

While there is a pronounced trend toward metal design in airplanes, it will be many years before wood is discarded, particularly in ships seating from one to six passengers.

Wood is stronger for its weight than any material except alloy steel and can be worked or fabricated much more cheaply until airplanes are built by thousands instead of hundreds. This time will come but it is still in the quite distant future.

A discussion of wood vs. metal from an engineering standpoint is beyond the scope of this book as is also a complete explanation of the engineering terms used in the table below. A brief comment, however, may suffice to make the terms clear enough for the purpose of comparing different woods. Fiber stress means the load in pounds per square inch. Elastic limit is the point at which, if the load is removed, the material will show no permanent set or damage. Modulus of rupture is the load in lbs. per sq. in. at which the material will break or "rupture". These terms apply to loads induced in bending. In straight compression the expression "maximum crushing strength" takes the place of "modulus of rupture".

The woods listed below are those used for structural purposes. For interior trim any of the "decorative" woods, such as walnut, birds-eye maple, etc., may be used, but strength is usually of no consequence under such conditions.

ASH - Commercial White. A strong, white, flexible, coarse grained wood. Used for wing tip bows, blocking, float or hull members and any bent members.

BASSWOOD - White, soft for a "hardwood", easily worked. Used chiefly as core of plywood which has hardwood faces, sometimes for blocking, seldom as a structural member.

BIRCH - Yellow-white, hard, strong, does not split easily. Used widely for plywood and to some extent for blocking where bolts pierce a beam, etc.

CEDAR - Port Orford. White, straight grained, easily worked, very stiff and strong. Used sometimes for wing beams and compression members, for hull and float members.

DOUGLAS FIR - Yellow-white, very similar to spruce and often used in place of it, especially for ribs and small members.

MAHOGANY - Brown, coarse grained, soft for a "hardwood". Used chiefly for plywood and for inside trim.

MAPLE - Satiny yellow, very hard. Used for bearing blocks, such as in beams where bolts pierce them.

PINE - Western white or Oregon. Very similar to spruce and used for same purposes.

SPRUCE - Yellow-white, straight grained and satiny, if good quality. Used in preference to all other woods for wing beams and other structural members.

Wood for airplane use is carefully selected and carefully kiln dried. An effort is made to have the moisture content about 15%,as less than this causes brittleness and brashiness and more tends to make the wood weaker. In fact, the selection and treatment of airplane wood is a science in itself. Further information may be ob-

WOODS USED IN
AIRPLANE CONSTRUCTION
(continued)

tained by writing the Government Printing Office, Washington, D.C., for a list of the bulletins of the Forest Products Laboratories and ordering those desired.

STRENGTH AND WEIGHT OF WOODS FOR AIRPLANE USE

Name of Wood	Weight in Pounds per Cubic Foot	Bending		Compression Parallel to Grain		Compression Perpendicular to Grain	Shearing Strength Parallel to Grain
		Fibre Stress at Elastic Limit	Modulus of Rupture	Fibre Stress at Elastic Limit	Maximum Crushing Strength		
Ash	41	8,900	14,800	5,250	7,000	2,250	1,380
Basswood	26	5,600	8,600	3,370	4,500	620	720
Birch	44	9,500	15,500	5,480	7,300	1,590	1,300
Port Orford Cedar	30	7,400	11,000	4,880	6,100	1,030	760
Douglas Fir	34	8,000	11,500	5,600	7,000	1,300	810
Mahogany	34	8,800	11,600	4,880	6,500	1,760	860
Maple	44	9,500	15,000	5,620	7,500	2,170	1,520
Oregon Pine	27	6,000	9,300	4,240	5,300	750	640
Spruce	27	6,200	9,400	4,000	5,000	840	750

Anyone familiar with wood will of course realize that the foregoing table includes only a very few of the hundreds of different kinds of wood found throughout the world. As stated above, however, there are only a few varieties which are suitable for airplane structures and are available in this country at a reasonable price. These are included in the table.

The airplane mechanic is naturally not expected to be an engineer or designer. However, he is often called on to make emergency repairs when the original material is not available and it is highly desirable to be able to compare the properties of the wood on hand with that of which the part was originally made. It is for this purpose that the table is included.

AIRCRAFT PLYWOOD

It has been found by laboratory tests that the strength of wood along the grains averages about 17 times as great as the strength across the grains. This fact makes it highly impractical to use veneer (a single thin sheet of wood) in aircraft construction, as either an excess of weight or a lack of strength results. To overcome the disadvantage of this variation of strength, plywood has been developed. This was done by gluing two or more sheets of veneer together with the grains running in opposite directions. The more plies, or sheets of veneer, the more constant is the strength ratio of the finished product. As can be readily seen, the strength of plywood depends upon the selection of the material for the plies and the characteristics of the glue.

After much experimentation with different materials, birch, mahogany and spruce were found to be the best for the various purposes. The glue presented a larger problem than the selection of material. At present three types of glue seem to answer the need for a strong, water-resistant glue; the blood albumin, casein and phenolic glues. With these glues it is possible to develop a glue bond capable of withstanding a shear stress of 350 pounds per square inch and over when it is dry and as high as 250 pounds when wet. By using carefully selected veneer and the proper glue a product has been made that possesses the properties of weight, hardness, strength and elasticity in practically constant ratios. This makes aircraft plywood truly an engineering material.

Aircraft plywood is furnished in many thicknesses, with a varying number of plies, the most popular size range being from 3/64" to 1/4" and from 3 to 5 plies. However, for special purposes it is furnished in standard sizes down to 1/40" in thickness, such as would be used on gliders, and can be had in standard sizes up to 1" for structural parts. By special order plywood can be purchased in any size from .030" - 3 ply, to 2" - 20 ply or over.

In the manufacture of plywood it has been found advantageous to make the ply that is in between two hardwood plies, of a soft wood, such as poplar or basswood. While this inside, or core ply, does not add much to the strength of the plywood, it does provide a stronger glue bond than if all hardwood were used. For this reason plywood is usually furnished in 3, 5, 7, 9, etc. plies, which allows a hardwood ply on each face with a soft wood filler or core ply, between each of the hardwood sheets.

Balsa wood is also used as a core ply when soundproofing plywood is made. This is used extensively in cabin linings as it serves both for insulating and soundproofing the cabin. This plywood is supplied in a variety of hardwood faces suitable for trim.

Plymetal is made by cementing an aluminum or dural face to a stiff plywood panel. This makes an exceedingly strong product which is approximately 50 times as stiff and has 6 to 8 times the impact resistance of sheet metal of the same weight. Plymetal is used for floorboards, baggage compartment linings, etc.

CASEIN GLUE

Casein glue is made from dehydrated milk curds which have been ground to a white or cream colored powder. It is used almost exclusively in aircraft construction due to its durability, convenience and economy. It was first introduced over twenty-five years ago and its value was proved by its use in the manufacture of water-resistant plywood for the airplanes of the World War period.

While the strength of a glue bond of any kind of glue depends upon the material and the fit of the surfaces, the pressure applied, atmospheric conditions at the time of drying, etc., under ideal conditions casein glue develops a bond capable of withstanding a shear stress well over 250 lbs. per square inch. Although this glue is often called waterproof, this is not strictly correct. It is, rather, water-resistant and the strength of this glue in a wet shear test is still over 125 lbs. per square inch. The wet shear test was made after specimens had been soaked in cold water for 48 hours.

Casein is a cold water glue, meaning that it is mixed for use with cold water (70 degrees Fahrenheit) and can be applied to cold lumber with equally good effects. These two items add greatly to the convenience of this glue. The fact that a very small quantity of glue can be mixed at one time, and that it does not have to be used immediately, and that the unmixed powder can be kept over a long period of time, if kept away from moisture, makes casein glue a very economical glue for the mechanic or for the factory. The time required for drying is somewhat greater than that of most other glues, taking approximately 24 to 48 hours to dry completely. However in most cases it is safe to work glued surfaces and joints after the material has been in the clamps for 12 hours.

HELPFUL HINTS IN USING CASEIN GLUE

1. Never use casein glue after it has been mixed for over four hours.
2. For gluing cracks in wood, use a thinner mixture which will run in and fill up the cracks.
3. Prepare all necessary clamps before applying the glue.
4. Where possible, put paper between the material and the clamping block to prevent the glue sticking the work to the blocks.
5. Make sure the surface to be glued is clean, free from all grease, paint, varnish, dirt, etc.
6. Glued joints must fit perfectly.
7. Wipe off all excess glue after clamping. When the glue dries, it is extremely hard on cutting tools and it also has the tendency to attract moisture even through varnish, which will cause the material to dry rot under the exposed glue.
8. A pressure of 175 lbs. per square inch is needed when gluing spruce to get the best result. Slightly higher pressure is needed for hard woods.
9. Glued material should never be removed from the clamps under 12 hours.
10. A small, soft brush is helpful in applying glue.
11. Never sandpaper surfaces to be glued, as the sandpaper dust clogs the pores of the wood.
12. Casein glue can be used to cement fabric to wood if the sizing is first removed from the fabric by rinsing in cold water.

HOW TO MIX CASEIN GLUE

One of the features of casein glue is that a small quantity can be mixed at one time, thereby saving glue. Ordinarily for small jobs such as repairing ribs etc., two or three tablespoons of the powder will make a sufficient quantity and if more is needed, a new batch can be quickly mixed.

MATERIAL: Casein glue, cold water (70 deg. F.)

TOOLS: Small wood paddle, glue pot (glass or porcelain preferred), measuring cup.

PROCEDURE:

1. Measure out the correct amount of powder for the job. This will be determined by experience only.

2. Measure the correct amount of water.
Note: There are several kinds of casein glue and slightly different proportions of glue and water are used in each case. The manufacturer's specifications should be followed. Ordinarily one part of water to one part of glue, by volume, is used.

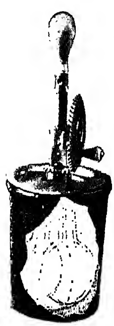
3. Pour the water into the glue pot.

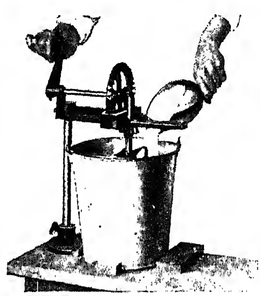
4. Stirring the water vigorously, add the powder slowly.

5. Stir rapidly for two minutes.

6. Let stand for 10 minutes.

7. Stir rapidly for one minute. The glue is now ready to be used and should be the consistency of thick cream.
Note: If the glue is too heavy, more water can be stirred in, but if it is too thin, do not add more powder as the added powder will lump. Mix up a small quantity of very thick glue by using less water and add to the original.





Two Types of Glue Mixers

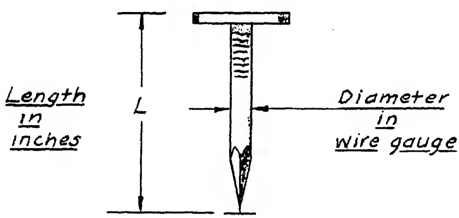
AIRCRAFT NAILS

After much experimentation with ordinary fasteners such as brads, escutcheon pins, wire nails, etc., it was found that each of these fasteners was unsatisfactory for aircraft work. Either they would corrode, loosen up, cut the thin plywoods, or for some other reason were discarded. The aircraft nail was developed to fill the need, and while it differs only slightly from the common flat head nail, these differences are worthy of note.

The aircraft nail is a flat head wire nail, but it is made of better material than the common nail, adding to its strength and durability. The size is designated by the wire gauge size for D and length is measured in inches. They are supplied in standard sizes from 20 to 16 gauge and from 1/4" to 1-1/2" long. They are also supplied in either brass or steel. If steel, the nail is either cement-coated or electrogalvanized to prevent rusting.

Aircraft nails are barbed to provide a greater gripping power in the wood and so they will not loosen under vibration. Cement coating roughens the surface of the nail, also adding to its holding power. These nails are needle pointed to permit easier starting in hard plywood.

Flat heads are used for two reasons: First, they do not cut through thin plywood as would a nail with a tapered head; second, they are flush with the surface, which does not increase the resistance, or skin friction.



AIRCRAFT NAIL

Hints in Using Aircraft Nails:

- It is very dangerous to carry nails in the mouth.
- In driving small nails, tweezers help considerably in holding the nail. A thin stick with a notch for the nail can be used also.
- In spacing or staggering nails in plywood, sharp dividers speed up the work by getting the exact location and starting a hole for the nail.

RIBS USED AS COMPRESSION MEMBERS

In addition to the ribs which are used entirely to maintain the contour of the surface, there are other members in a wing to hold the spars apart and act as a portion of the drag truss. See Wing Nomenclature. In some cases these members are used also as form ribs. However, they are made much stronger and more substantial than the regular ribs. If they act as form ribs they are usually made from a solid sheet of plywood with reinforcements on each side as shown in Fig. I, or in the shape of a box, with plywood sides and spruce capstrips, as shown in Fig. II. Of the two types, that shown in Fig. I is the cheaper, and, in most cases, better.

It is not always convenient however, to lay out the drag truss so that the compression members come at a location which would be desirable for the form ribs. Furthermore, many designers consider it uneconomical to build special ribs for compression members. In such cases the compression member is usually a round tube of steel or dural, attached to the spar by suitable fittings. See Fig. III. This is probably the simplest type of construction possible.

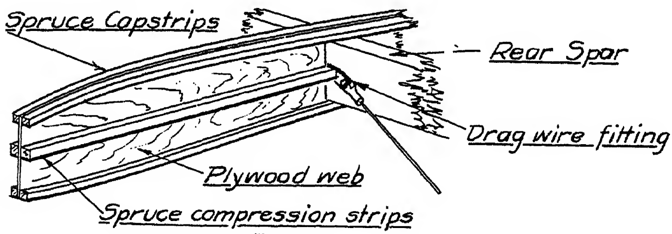
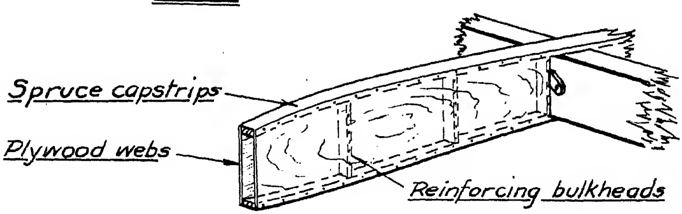


FIG. I



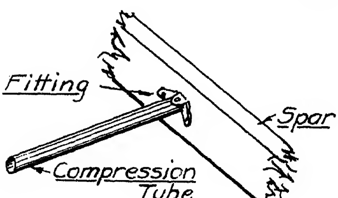


FIG III

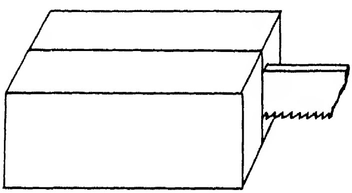
rib at the inner end of the wing, usually called the butt rib, in most cases must act as both a form rib and compression member. This rib is customarily made as in Fig. I, except that the capstrips and reinforcements are on one side only, so as to keep the end of the wing smooth.

WOODWORKING TOOLS

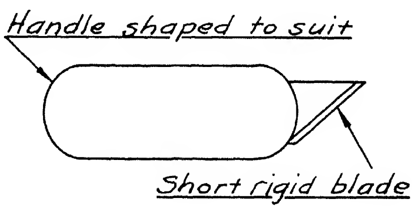
It is the mechanic's duty to learn how to use the various tools required by the trade. Naturally, only experience will enable a person to acquire the skill and proficiency desired, however, there are many things about the use of tools that can be learned from printed instructions. Space does not permit a complete discussion of the use of woodworking tools in this book, and as this information may be readily obtained elsewhere, the omission is felt justifiable. A visit to any library will reveal several good books dealing with principles and techniques of using wood tools. Several tool manufacturers publish pamphlets on the care and use of their products which will be found to be of great value.

The Stanley Rule and Level Plant of New Britain, Connecticut publish a series of instruction sheets designed to illustrate the selection, care and use of a number of woodworking tools. One of these sheets is reproduced on the following page so that anyone interested may see the type of information that is available from this source. At present this company produces 34 of these sheets dealing with such items as hand saws, planes, screwdrivers, hammers, wood chisels, cold chisels, drills, etc. These pages are available at 1/2¢ each, or 17¢ a set. The individual pages measure 8" x 10-1/2" and are punched to fit in a loose leaf note book. The same information is published in booklet form called "The Stanley Tool Guide", and retails for 25¢ a copy. It is the authors' opinion that these instruction sheets would form a valuable addition to any mechanic's notes and would prove especially beneficial to the beginner.

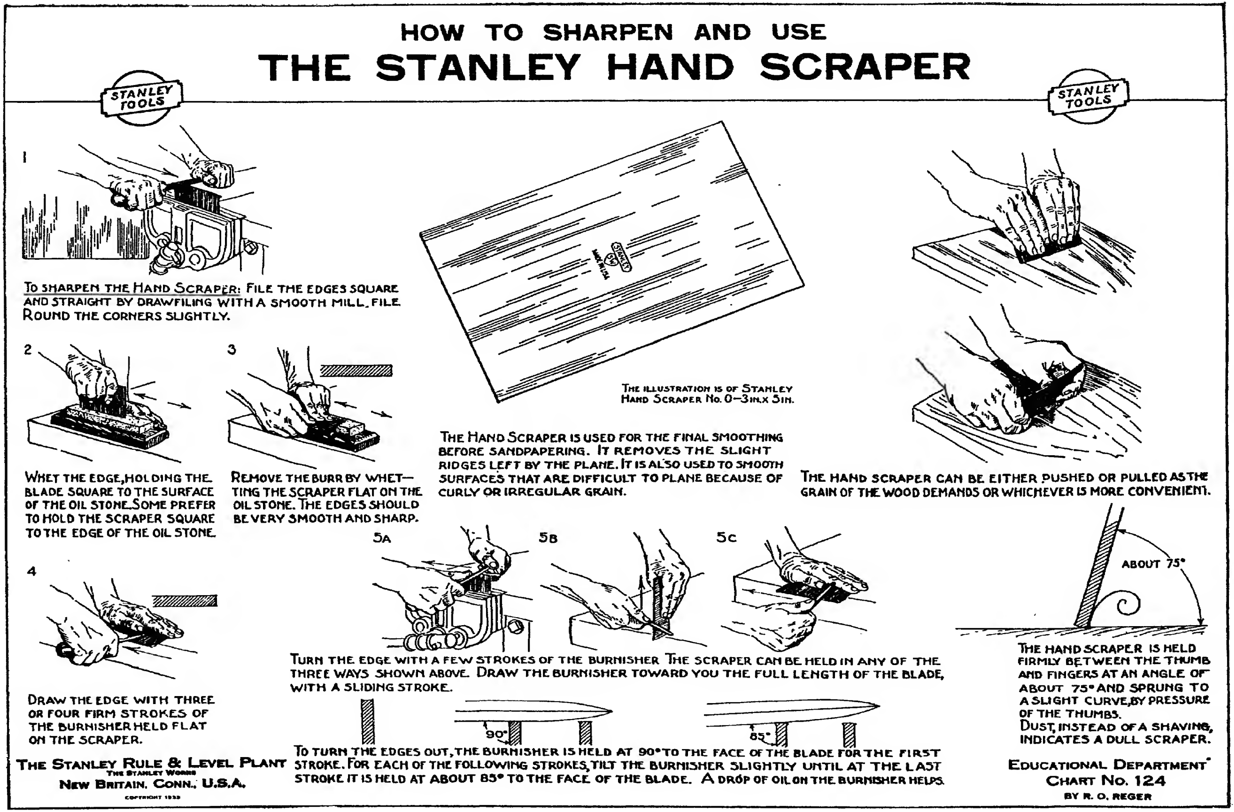
In addition to the standard woodworking tools, a "plywood knife" similar to the one illustrated below will be found to be of utmost convenience in a great many jobs. A knife of this type can be purchased, but it is usually more practical to make it. The handle is made from two blocks of soft wood of any suitable size. Before the blocks are shaped the inside surface of one is recessed to receive a short length of a broken power hack saw blade. This may be done with a narrow wood chisel but care should be taken to make sure that the cut is not too large, for the blade must fit snugly in order to produce a rigid knife. The two blocks with the blade insert are glued and clamped. After the glue has set the handle may be shaped and the blade sharpened on an emery wheel. Power hack saw blades make excellent cutters if care is taken not to overheat them when sharpening. The handle may be further reinforced by whipping it with rib lacing cord and doping.



Heavy blade between blocks



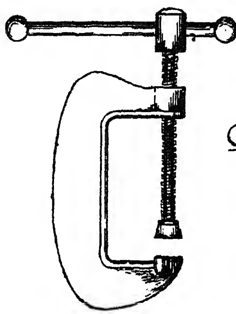
Completed Plywood Knife


HOW TO SHARPEN AND USE
THE STANLEY HAND SCRAPER
STANLEY TOOLS
STANLEY TOOLS
1
TO SHARPEN THE HAND SCRAPER: FILE THE EDGES SQUARE AND STRAIGHT BY DRAWFILING WITH A SMOOTH MILL FILE. ROUND THE CORNERS SLIGHTLY.
2
3
WHET THE EDGE, HOLDING THE BLADE SQUARE TO THE SURFACE OF THE OIL STONE. SOME PREFER TO HOLD THE SCRAPER SQUARE TO THE EDGE OF THE OIL STONE.
REMOVE THE BURR BY WHETTING THE SCRAPER FLAT ON THE OIL STONE. THE EDGES SHOULD BE VERY SMOOTH AND SHARP.
STANLEY
SW
MADE IN U.S.A.
THE ILLUSTRATION IS OF STANLEY HAND SCRAPER NO. 0—3IN. X 5IN.
THE HAND SCRAPER IS USED FOR THE FINAL SMOOTHING BEFORE SANDPAPERING. IT REMOVES THE SLIGHT RIDGES LEFT BY THE PLANE. IT IS ALSO USED TO SMOOTH SURFACES THAT ARE DIFFICULT TO PLANE BECAUSE OF CURLY OR IRREGULAR GRAIN.
THE HAND SCRAPER CAN BE EITHER PUSHED OR PULLED AS THE GRAIN OF THE WOOD DEMANDS OR WHICHEVER IS MORE CONVENIENT.
4
5A
5B
5C
ABOUT 75°
DRAW THE EDGE WITH THREE OR FOUR FIRM STROKES OF THE BURNISHER HELD FLAT ON THE SCRAPER.
TURN THE EDGE WITH A FEW STROKES OF THE BURNISHER. THE SCRAPER CAN BE HELD IN ANY OF THE THREE WAYS SHOWN ABOVE. DRAW THE BURNISHER TOWARD YOU THE FULL LENGTH OF THE BLADE, WITH A SLIDING STROKE.
90°
85°
TO TURN THE EDGES OUT, THE BURNISHER IS HELD AT 90° TO THE FACE OF THE BLADE FOR THE FIRST STROKE. FOR EACH OF THE FOLLOWING STROKES, TILT THE BURNISHER SLIGHTLY UNTIL AT THE LAST STROKE IT IS HELD AT ABOUT 85° TO THE FACE OF THE BLADE. A DROP OF OIL ON THE BURNISHER HELPS.
THE HAND SCRAPER IS HELD FIRMLY BETWEEN THE THUMB AND FINGERS AT AN ANGLE OF ABOUT 75° AND SPRUNG TO A SLIGHT CURVE, BY PRESSURE OF THE THUMBS.
DUST, INSTEAD OF A SHAVING, INDICATES A DULL SCRAPER.
THE STANLEY RULE & LEVEL PLANT
THE STANLEY WORKS
NEW BRITAIN, CONN., U.S.A.
EDUCATIONAL DEPARTMENT
CHART NO. 124
BY R. O. REGER

USE OF CLAMPS

As has been mentioned before, casein glue is used in practically every part of the airplane including many structural parts, as it develops a shear strength of 250 lbs. per square inch and over. It must be remembered that the strength of this glue bond has been counted upon, and if it were to fail the part would be greatly weakened, possibly to the point of failure. In making repairs it is possible to make a glue bond of the required strength, but not unless you are exceedingly careful.

In factories where glue is used, large glue presses are found and many similar pieces of material are placed in the press at the same time, where sufficient pressure, evenly distributed, can be easily applied. The mechanic has to depend upon clamps to provide the required pressure.

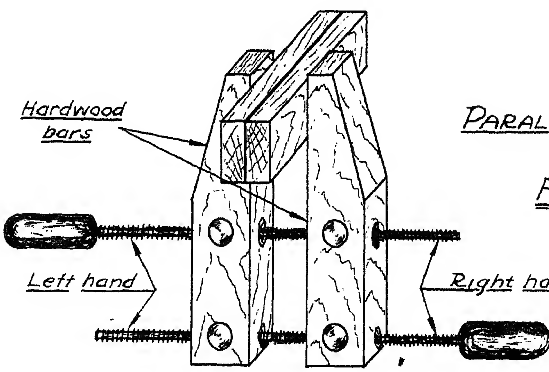


C CLAMP

FIG. I

Hand clamps are used as they are suitable for a great variety of jobs. Outside of their being used to provide clamping pressure they are also used to hold metal parts while assembling, holding sheet metal to be sawed, clamping temporary jigs, templates, etc.

There are two main types of clamps used by the mechanic, the iron C clamp, Fig. I and the wood parallel clamp, Fig. II. The C clamp is many times more convenient to use than the wood clamp, as it takes up less room and is capable of exerting a higher concentrated pressure. In using a C clamp, clamping blocks or caul blocks must always be placed between the work and the metal jaws of the clamp to prevent dents in the material. This is unnecessary with the parallel clamp, as the jaws are made of wood. The most popular sizes of C clamps range from the small 2" clamp, used in repairing ribs etc. to the heavy 10" or 12" clamp, used for repairing heavier parts.



PARALLEL CLAMP

FIG. II

USE OF CLAMPS
(Continued)

The wood parallel clamp is considered better for general all around use, but it is a little harder to use correctly. To get the full benefit of this clamp the bars must be parallel after sufficient pressure has been applied. In use, the clamp is adjusted to the proper size by turning both handles. After the proper size has been reached, turn the bottom handle until the bars are slightly wider at the jaw end. Slip the clamp into position and bring the bars back to parallel by turning the bottom handle, as shown in Fig. III. If the bars go past parallel before sufficient pressure is applied, remove the clamp, reduce the space between the bars and try again.

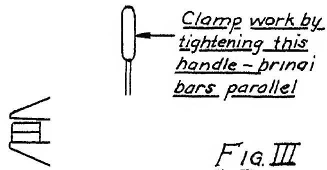


FIG. III

In making a good glue bond many factors must be considered. The surfaces must fit correctly, the glue must be used properly and sufficient evenly distributed pressure is required. The use of a glue press, where available, is always recommended. To make a glue bond that can be depended upon, casein glue requires a pressure of 175 lbs. per square inch for spruce and slightly higher for hardwood. In order to make sure that all portions of the glued surface receive the correct amount of pressure, caul blocks are used to distribute the concentrated load from the clamps. Caul blocks should be large enough to cover the entire glued surface, as shown in Fig. V. The somewhat exaggerated result of using small caul blocks is shown in Fig. IV.

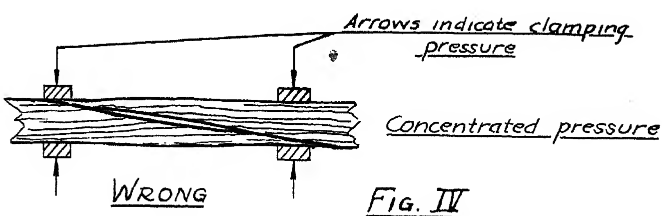


FIG. IV

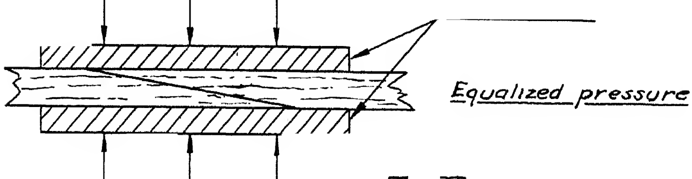


FIG. V

IGHT

LEADING EDGE STRIPS

The leading edge strip must be strong enough to withstand the pull of the fabric when it is doped and the additional air load, without bending. It should also be as light as possible and easy to attach to the ribs. A popular type of leading edge strip, designed for a wing with an open nose section, not covered with plywood or dural, is illustrated in Fig. I. This strip is fitted into the slot or gap between the capstrips, where it is glued and nailed. This strip is very light, yet it resists bending because of its width.

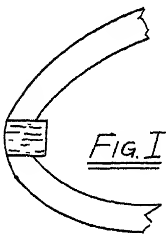


FIG. I

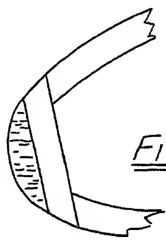


FIG. II

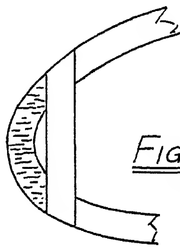


FIG. III

EDGE

While a leading edge strip of the type shown in Fig. I will answer the requirements of being strong, light, and easily attached, it necessitates a sharp bend in the capstrip. In many type ribs the capstrips would have to be steamed before this bend could be made. This would add to the cost of the rib construction and can be avoided by employing construction similar to Fig. II. A strip of this type is comparatively heavy, so is often machine routed to save weight, as seen in Fig. III.

If fairing is applied to the upper part of the nose section, the leading edge strip must be designed to withstand the nailing of the cover without splitting. For this reason the quarter-round strip shown in Fig. IV is often used.

Where the entire leading edge section is enclosed by fairing, the cover can be securely fastened to the spar and each rib, which makes it unnecessary to depend upon the leading edge strip for nailing. As the strip does not have to be made large enough to withstand nailing, and as the entire section is strengthened by the fairing, a strip of the type shown in Fig. I is used. Any of the above type strips can be further reinforced against splitting by lamination.

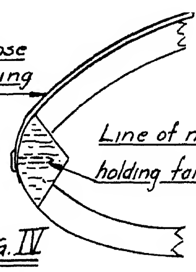


FIG. IV

HOW TO MAKE A LEADING EDGE STRIP

It is unnecessary to make a full length leading edge strip to learn the principles and operations involved. The instructions given below are for making a four foot length of the correct size and shape to fit the rib constructed as per directions given on a preceding page.

MATERIAL: Spruce, 1" x 3" x 4'; fine sandpaper; small piece of pyralin.

TOOLS: Jack plane, block plane, marking gauge, scriber, knife.

PROCEDURE:

1. Cut the pyralin to a convenient size, 3" x 5" will do.

2. Square up one 5" edge and mark it "working edge".

3. Place the pyralin on the full size drawing in such a manner that the working edge is even with the rear of the leading edge strip. Hold the pyralin firmly in position and with the scriber carefully mark the curve on the pyralin. See Fig. I.

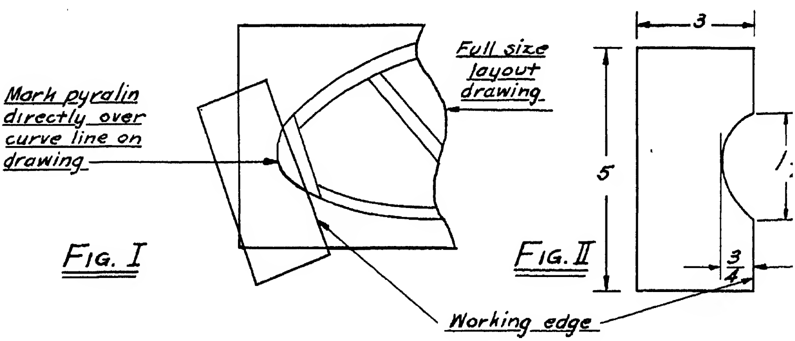


FIG. I

FIG. II

4. Cut out the pyralin from the working edge to the curve. Check the measurements with Fig. II.

Note: If no pyralin is available, you may use celluloid or transparent paper to find the curve and then transfer it to stiff metal from which the template can then be made. If this method is used, check the results carefully.

5. Square the spruce to 3/4" x 2".

6. Square both ends.

7. With the template, lay out the curve on each end, taking care that the template is held in the same position each time. Fig. III.

HOW TO MAKE A LEADING EDGE STRIP
(Continued)

8. Determine the greatest amount that can be taken off in a straight line and mark this off with a straight edge. Fig. IV. From the points where this line meets the face and edge of the strip, gauge a full length line.

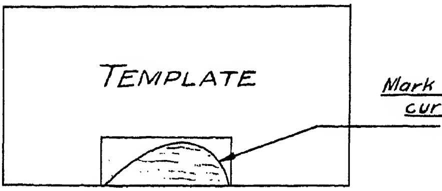
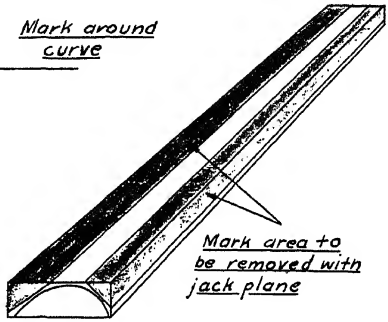


FIG. III

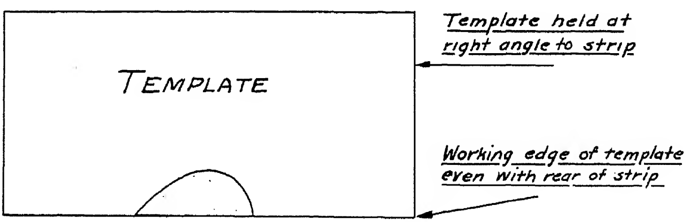
FIG. IV



9. Plane the corners down to the lines with the jack plane, being careful not to plane under the lines. (Shaded area on Fig. IV.)

10. Round the strip to the proper curve with the block plane. Use the previously made template to check your work as you proceed.

CAUTION: Always hold the template at right angles to the strip. The working edge of the template should be in a straight line with the rear of the leading edge strip.



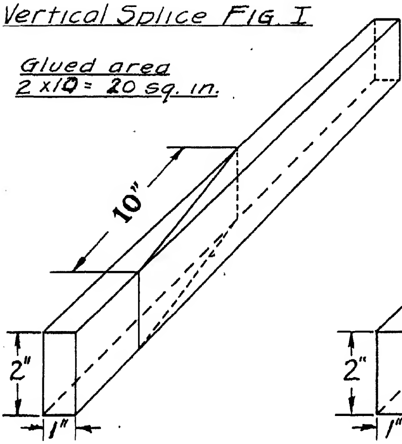
11. The finished leading edge strip should be sanded to remove any plane marks.

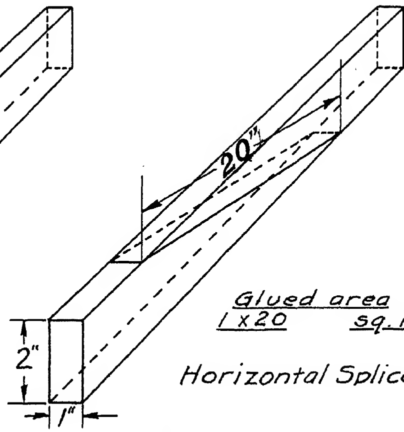
12. Check the curve of the leading edge strip by trying it on the nose of the rib.

LEADING EDGE STRIP SPLICES

The Civil Aeronautics Authority requires that all splices in wood must have a glued surface ten times as great as the cross section area. It has been found that this much glued surface is necessary to develop the full strength of the original member. The actual direction and location of the splice is largely governed by the shape of the strip and the location of the break. If possible, the splice is cut in the vertical plane of the member, as the splice can be made shorter and still provide the correct gluing surface, as illustrated in Figures I and II. Both of these splices have a total glued area of 20 sq. in. However, the splice in Fig. I which is made in the vertical plane, need be only 10" long, whereas the other must be 20" long. Needless to say, the shorter splice is easier to make.

Vertical Splice FIG. I

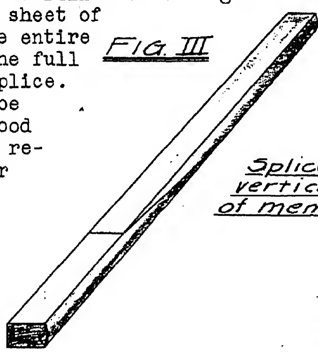




Horizontal Splice FIG. II

A leading edge strip of the type shown in Fig. III is usually spliced in its vertical plane, and reinforcing blocks are glued on both sides to strengthen the splice. To determine the size and thickness of the reinforcing blocks, the regulations covering a solid spar splice are used. If the strip is routed, a reinforcing block which has been shaped to fill the routing is used. It is good practice to glue and nail a sheet of plywood over the entire rear face for the full length of the splice. Splices should be glued only. A good splice does not require nailing or wrapping.

FIG. III



Splices cut in vertical plane of members

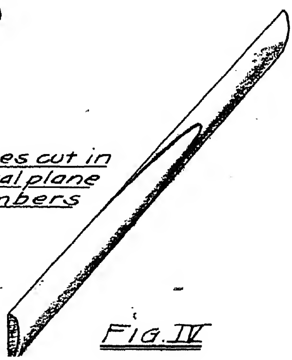


FIG. IV

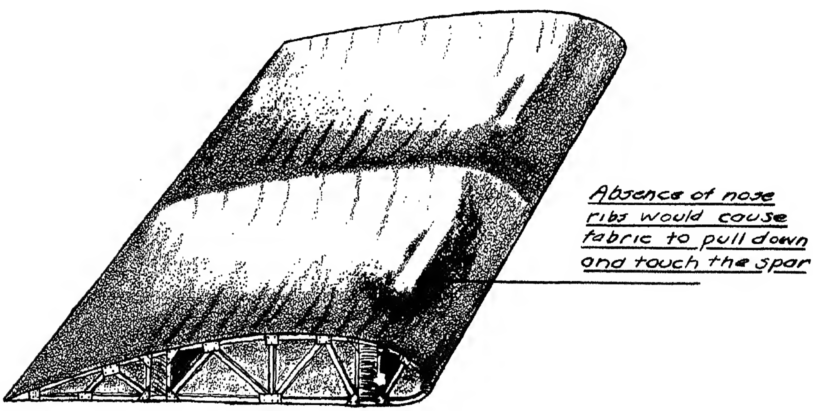
LEADING EDGE SECTION

The leading edge section of a wing is that part of a wing which extends forward from the front spar. This is also called the entering edge section, or the nose section. See complete wing drawing. The curve or camber of this section greatly affects the efficiency of the airfoil, as this is the portion that directs the air around the airfoil.

When the fabric is put on a wing and doped, the dope tightens the fabric and this tightening tends to draw the fabric into a straight line from the leading edge strip to the trailing edge strip, instead of following the camber of the form rib. This not only reduces the curve of the leading edge, but it actually makes a thinner airfoil section between the ribs. This is illustrated below. To help correct this condition a false, or nose rib, of the same camber as the form rib, is placed in the leading edge section between each form rib.

Many manufacturers cover the upper portion of the leading edge section with thin plywood or dural from the leading edge strip to the top of the front spar. This is called nose fairing. Dural is probably more popular than plywood, as the latter sometimes warps in damp weather. In a leading edge section covered in this manner, a heavier leading edge strip must be used to permit the fastening of the fairing.

Still another method used to preserve the camber is to cover the entire nose section with dural or plywood. When a fairing of this type is put on, it is fastened by nails to the spar and is also firmly nailed to each form and nose rib. This considerably strengthens the entire section, preserves the camber perfectly, and eliminates the need for a heavy leading edge strip.



TRAILING EDGE STRIPS

WOOD:

One of the first types of trailing edge strips to be used on wood ribs was of the solid V construction. This section is shaped to carry out the camber of the rib. Due to the pull of the fabric on the trailing edge strip, this V section could not be carried out to form a sharp edge, as wood so thin would have a tendency to split. This necessitated a rather blunt trailing edge on the wing, which detracted somewhat from the streamlining of the trailing edge section.

WIRE:

Wire trailing edges are no longer used to any great extent. Although a wire provides a strong, light trailing edge, it has the disadvantages of being difficult to repair and producing an unsightly scalloped trailing edge.

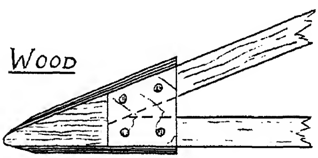
TUBE:

Some manufacturers use a trailing edge strip of brass tubing, held on by metal straps which are riveted through the capstrips. This answers the need for a non-rusting strip that will keep a straight trailing edge and still not pull out of place easily. As brass tubing is quite heavy, it is being rapidly replaced by aluminum tubing. Aluminum tubing is also used in a streamlined section. It is attached by filing openings at the rib locations and riveting directly to the capstrips.

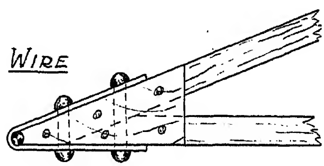
CHANNEL:

Probably the most popular type of trailing edge strip for either wood or metal ribs is the metal channel. This type of strip is easily attached with rivets, and is strong, rust-resisting, light and streamlined. The strip is formed by bending in a machine brake to the desired shape.

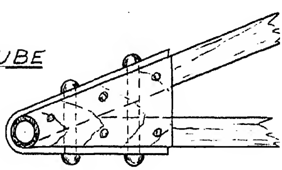
WOOD



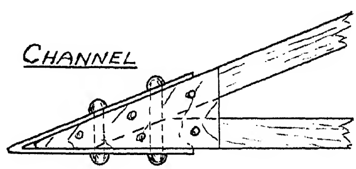
WIRE



TUBE



CHANNEL



WING SPARS

The most important members in a wing from the standpoint of safety, are the spars or beams. They also are the heaviest, their combined weight being over half the total weight of the wing. This being the case, all sorts of shapes have been devised in an effort to make them lighter and still have the proper strength. The most common of these shapes are shown below.

For small ships, no material has so far been found which is superior to wood, all things considered. When airplanes are built in real production lots of many thousand identical models, it will be worthwhile to develop dies or rolls to make spars of metal, probably stainless steel. At present, designs are changing so rapidly that seldom more than a few hundred ships are identical, and expensive dies are not warranted. Hence, this discussion is confined to wooden spars.

On large transport ships metal spars are customary, chiefly because it is difficult to obtain wood suitable for airplane use in such large sizes and because such ships have their wings covered with metal, which can be more satisfactorily attached to metal spars. This will be taken up under Metal Work.

Spars are subject to two kinds of loads at the same time, bending or side load and compression or end load. The diagram below shows a monoplane wing with a lift strut which illustrates the loads mentioned.

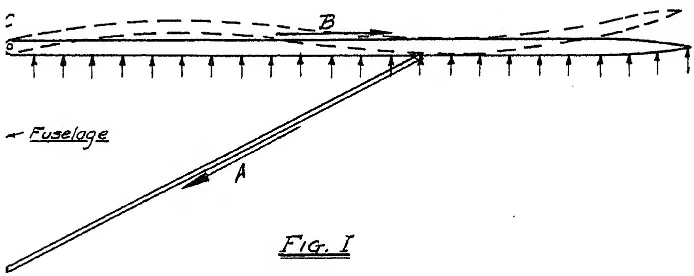


FIG. I

The small vertical arrows show the force exerted by the air in lifting the ship. If it were not for the strut the wing would, of course, rotate about the hinge C and fold straight up. The arrow A illustrates the force (tension) in the strut holding the wing down and the arrow B shows the force (compression) induced in the beam or spar by the pull of the strut. The dotted lines indicate the way the beam tends to deflect or bend. As a matter of fact, if you are riding in a light ship in "bumpy" air, you can often see the beams bend just as shown, though, of course, not so much in proportion.

WING SPARS
(continued)

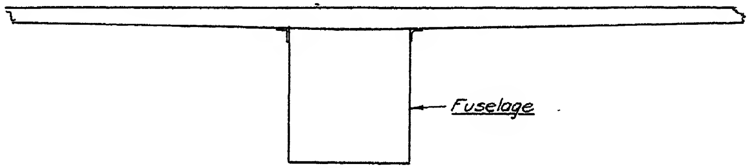


FIG. II

The question now arises in one's mind: What about cantilever wings, with no struts or wires to hold them down. These are either made with the beams running clear through from wing tip to wing tip, Fig. II, or else have two hinges for each beam, Fig. III, the type shown in Fig. II being preferred.

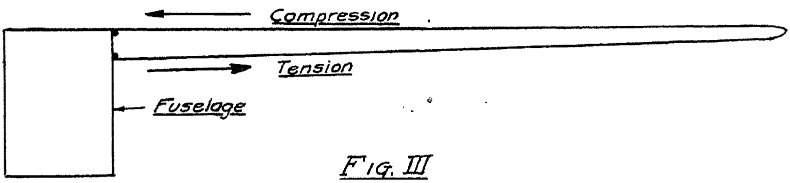


FIG. III

Spars are usually made with the top and bottom heavier than the center. This is because the outer portions of the spar carry most of the load. If a beam is supported at the ends and a weight placed in the middle as shown in Fig. IV, the top is carrying compression which gets less and less as the center is approached, and the bottom is carrying tension, which likewise gets less toward the center. Where the tension and compression meet there is, of course, neither. This line is called the "neutral axis".

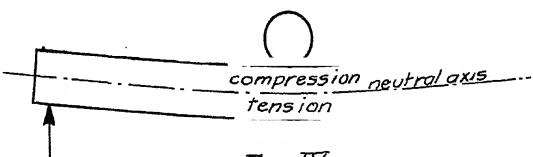


FIG. IV

There is another kind of load along this axis, however, known as "longitudinal shear". If two pieces of wood, representing the top and bottom sections of a beam, are set up and loaded they tend to slide by each other as shown in Fig. V.

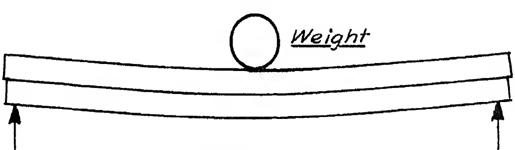


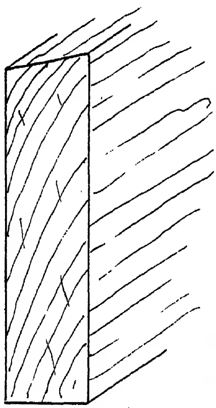
FIG. V

WING SPARS
(continued)

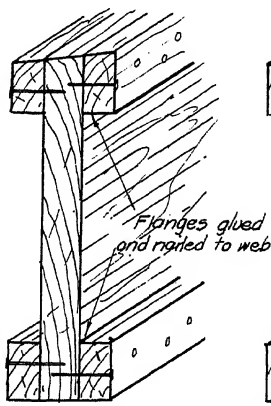
To prevent the top and bottom portions of a beam from sliding by each other in this manner and thus splitting the beam, a certain amount of material must be left in the center.

Under "Woods" will be found a discussion of the woods used in airplane construction. That most commonly used for spars is spruce, but Douglas fir, Oregon pine and Port Orford cedar are sometimes employed.

The drawings below show the more usual sections in wooden spars. That shown in Fig. VII is probably the most popular because there is little waste and the construction is not expensive. At points where fittings are attached the beam is either left solid (if routed) or filled in with blocks to make a solid rectangular section.

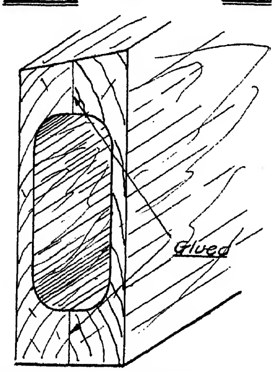


Solid Rectangular
FIG. VI

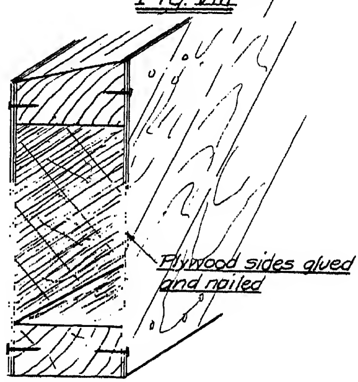


Built-up
FIG. VII

Routed I-Beam
FIG. VIII



Hollow Routed (Uncommon)
FIG. IX



Box Beam
FIG. X

HOW TO MAKE A BUILT-UP I-BEAM

MATERIAL: Spruce, 5/8" x 10" x 76", 5/8" x 8" x 76", 7/8" x 6" x 76", 7/8" x 2-3/4" x 36"; casein glue; flat head wood screws, 6 doz. #6 x 3/4", 6 doz. #6 x 1-1/4"; sandpaper

TOOLS: Jack plane, block plane, clamps, bevel protractor, screw driver, hand drill; 3/32", 9/64", 1/4" twist drills; countersink, back saw, cross cut saw, soft glue brush, dividers

PROCEDURE:

1. Dress the spruce to the following sizes:
   Front spar -
   One piece 1/2" x 5-3/16" x 76"
   Two pieces 1/2" x 2" x 76"
   Two pieces 1/2" x 1" x 76"
   Rear spar -
   One piece 1/2" x 4-9/16" x 76"
   Four pieces 3/4" x 1" x 76"

Note: Leave the flanges slightly full, or over the finished dimension to allow for dressing.

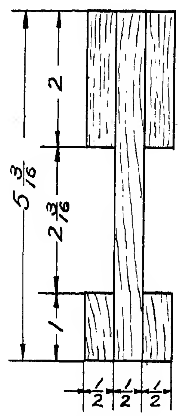


FIG. I

2. Referring to Figures I, II, and III, place the flanges on the web correctly and mark the faces to be glued.

3. Check all glued faces to make sure they fit together squarely.

4. Mix a quantity of casein glue.

5. Prepare all the necessary clamps and caul blocks to clamp the spars.

Note: It is important that the spar be kept straight while it is being glued. It is a good practice to use one long, heavy, smoothly surfaced timber for the bottom caul block and a somewhat lighter, but equally well surfaced caul block for the top. If this is done, the straightness of the spar will be assured.

6. Spread the glue over the gluing faces with a soft brush.

7. Clamp the spars, making sure that the flanges are arranged as shown in Figures I and II.

8. After twelve hours, remove the spars from the clamps and dress to the exact width of the spar opening in the rib.

Note: The width of the front beam is 1-1/2", while the width of the rear beam is 2".

Rear spar

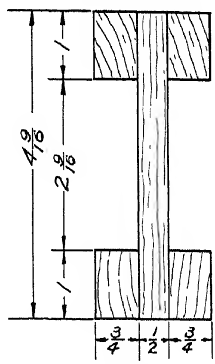


FIG. II

HOW TO MAKE A BUILT-UP I-BEAM
(continued)

9. Set the bevel protractor to the angle required for the spar to fit the top and bottom camber of the spar opening in the rib, and mark the correct angle on the ends of the beam.

10. Using the bevel protractor to check your work, dress the spars to a snug fit in the rib. Fig. IV.

11. Check the spar size by slipping a rib over the entire length of the beam.

12. Divide each flange into three equal parts, and with a pencil scribe these lines the full length of each flange.

13. Set the dividers at 4" and starting approximately 1" from the butt end of each flange, mark off 4" distances on the pencil lines. This is for the locations for the wood screws and these marks should be staggered as shown in Fig. V.

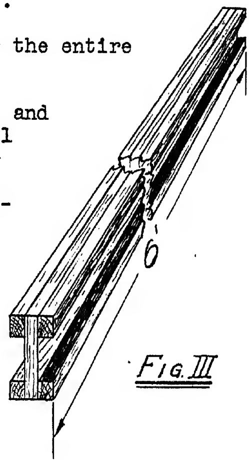


FIG. III

14. Drill the guide holes for the wood screws, using the 9/64" drill for the first hole and the 3/32" drill for the second hole.

Note: Complete information for drilling guide holes is given in the sheets on Wood Screws and Their Uses.

15. Countersink the guide holes for the flat head wood screws.

Note: The diameter of the countersink should be slightly less than the diameter of the wood screw head.

16. Drive the screws into the flanges with the correct size screw driver, making sure that the heads are exactly flush with the flanges.

17. Select and square one end of each beam.

18. Make two compression blocks for the butt end of each beam by cutting the 2-3/4" strip into 8" lengths.

19. Dress the compression blocks to a snug fit between the flanges as shown in Fig. V.

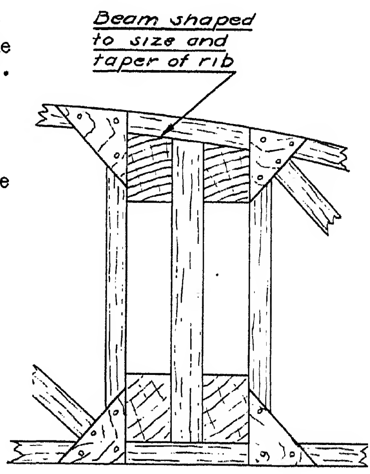


FIG. IV

HOW TO MAKE A BUILT-UP I-BEAM
(continued)

20. Set the bevel protractor at 30° and mark the fish mouth cut on one end of each compression block, as shown in Fig. V.

Note: The Bureau of Air Commerce requires that the angle of this fish mouth cut be 30° or less. The points of the fish mouth may have a 1/4" radius. Fig. V.

21. At the intersection of the two angle lines, drill a 1/4" hole tangent to each line. This is done to give the inside of the fish mouth a 1/4" radius. Fig. V.

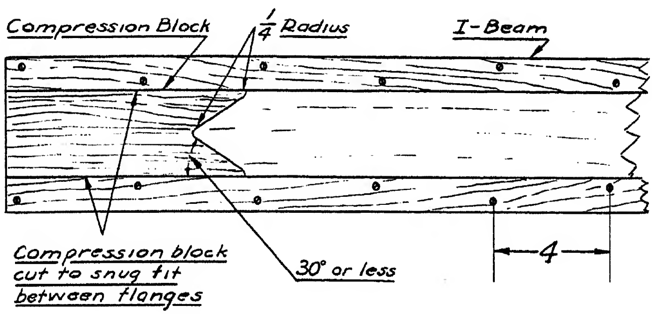


Fig. V

22. Glue and clamp the compression blocks into place.

23. After 12 hours remove the clamps and carefully dress the compression blocks to the thickness of the beam.

24. The spars cannot be cut to length until the actual length is determined by the curve of the wing tip bow. As soon as this is known, cut the spars to length.

25. As the wing tip bow fastens to the very bottom of the rear beam, this beam is tapered straight down from the last rib to a point 3/4" from the bottom of the beam.

26. Place the wing tip bow in the correct position and mark its location on the end of the front beam.

27. Taper the front beam down from full size at the last rib to the location marks of the wing tip bow.

28. Sand the beam thoroughly.

29. When the wing tip bow is attached to the beams, the end of each beam will have to be cut at an angle to fit the curve of the bow.

SPLICING WING BEAMS

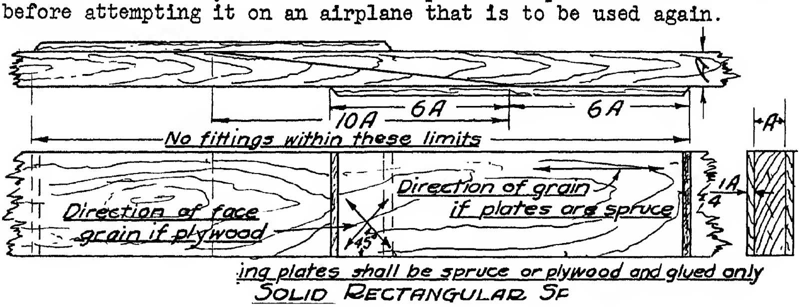
The following regulations in regard to splicing wood wing beams are contained in Civil Air Regulations bulletin No. 18, except for the numbers of the illustrative drawings.

"Wood spars may be spliced at any point, except at a wing fitting, which shall not overlap any part of the splice. (Note: In view of the usual poor joint obtained by making scarfs for a spar splice with a saw and plane, it is recommended that a joiner be used). Approved methods of splicing the various types of spars are shown in the drawings on the following pages.

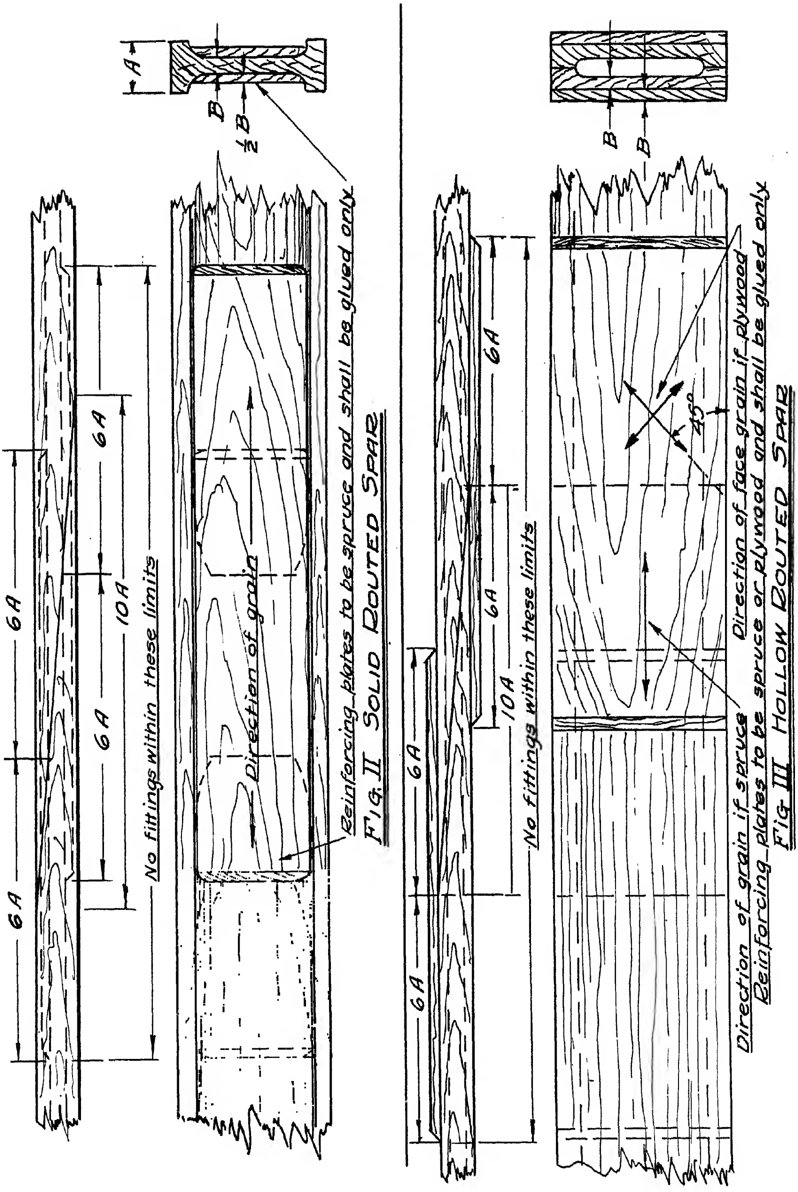
"All scarfs shall be made with a 10 to 1 slope and all joints shall be made with the highest quality of casein or animal glue. (Note: Casein glue is recommended for soft woods such as spruce, and animal glue for hardwoods such as plywood and ash). When casein glue is used on soft woods, a pressure of 100 to 150 pounds per square inch shall be applied to the joint during the gluing process. In gluing hard woods a pressure of 200 to 250 pounds per square inch shall be applied.

"In cases of elongated bolt holes in a spar, a new section of spar shall be spliced in or the spar replaced entirely. Except at a fitting, cracked spars in which the cracks are longitudinal and the wood is not splintered may be repaired (except on box spars) by gluing to both sides of the spar, strips of spruce or plywood of sufficient thickness to develop the longitudinal shear strength of the spar, such strips to extend well beyond the termination of the cracks. When this is done a total thickness of spruce equal to the thickness of the spar web, or a total thickness of plywood equal to one-half the spar web thickness shall be used, as shown in the following pages."

As to using the saw and plane to make the joint, this is of course necessary if one part of the spar to be spliced is still in the wing. Sandpaper should not be used on surfaces which are to be glued, on spars or anything else. The joint should fit perfectly before gluing, and great care should be taken that when the two parts are put together, the spar is straight in both directions. The rules of gluing as laid down in the sheets on that subject should be strictly followed. Splicing a spar is probably the most difficult and exacting woodworking job the mechanic is likely to be called on to do, and a number of practice splices should be made before attempting it on an airplane that is to be used again.



SPLICING WING BEAMS
(continued)



SPLICING WING BEAMS
(continued)

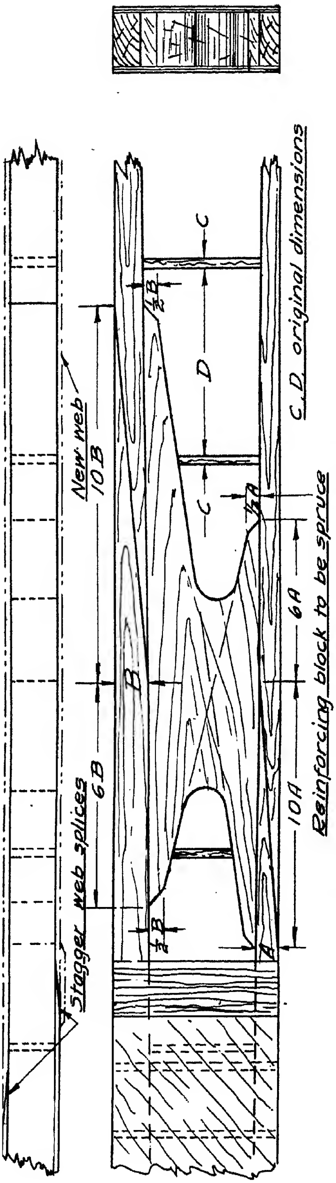


FIG. IV SPLICING BOX SPAR FLANGES - METHOD No. 1.
(See Fig VI for method of splicing plywood webs)

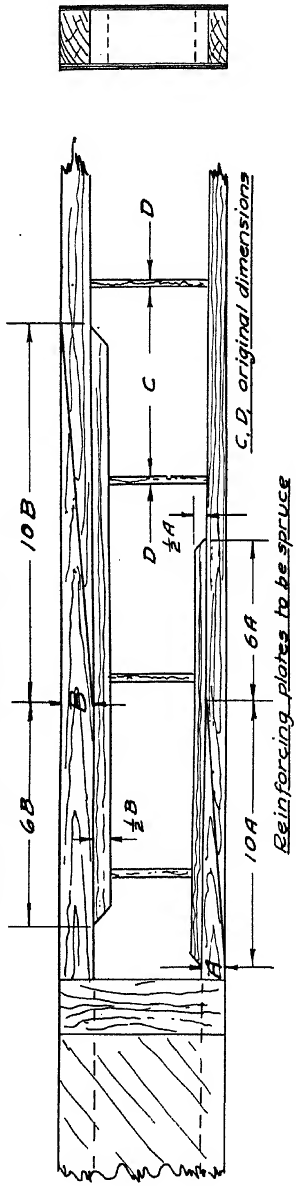


FIG. V SPLICING BOX SPAR FLANGES - METHOD No. 2
(See Fig. VI for method of splicing plywood webs)

SPLICING WING BEAMS
(continued)

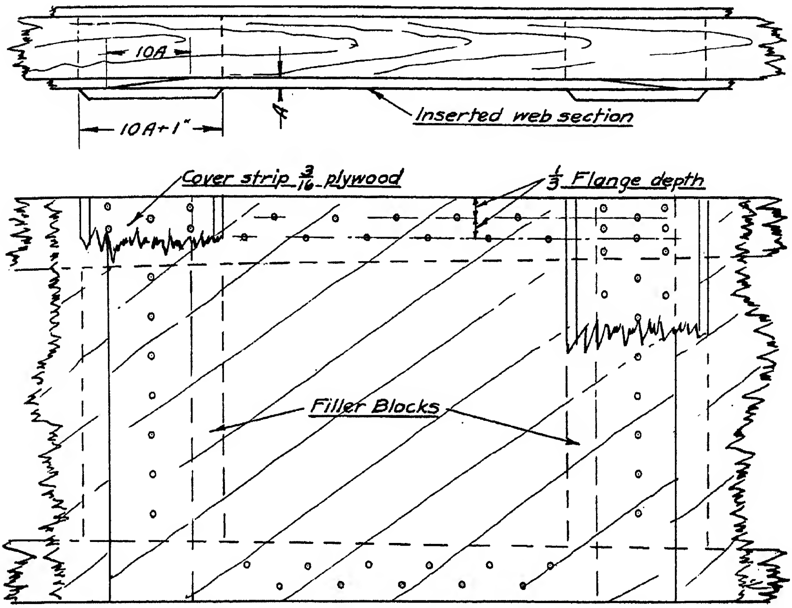


FIG. VI - METHOD OF SPLICING BOX SPAR WEBS

"NOTES:
1. After inserted web has been glued and nailed in place, glue cover strip over entire length of splice joints.
2. Sectional shape of filler blocks must conform exactly to taper of spar. They must not be too tightly fitted or wedging action will loosen existing glue joints of webs to flanges. If too loosely fitted, crushing of web will occur when clamping."

There are several little tricks in cutting the scarf joints for splices which will help materially in making the job a good one. After one portion of the beam has been cut with a saw, it should be run over a jointer, if one is available. If not, the surface should be smoothed with a plane and checked with an accurate straight-edge. The other portion should be cut with saw to match as closely as possible. By rubbing colored chalk on the finished surface and then holding the two parts together and sliding one on the other slightly, the chalk will rub off on the high spots of the piece to be finished. These spots can be planed off until a perfect fit has been obtained, after which the chalk should be completely removed from both surfaces with a scraper, being careful not to spoil the fit. Then proceed with the completion of the splice as shown in the illustration for the particular type of spar, following the directions given elsewhere for gluing.

SPLICING WING BEAMS
(continued)

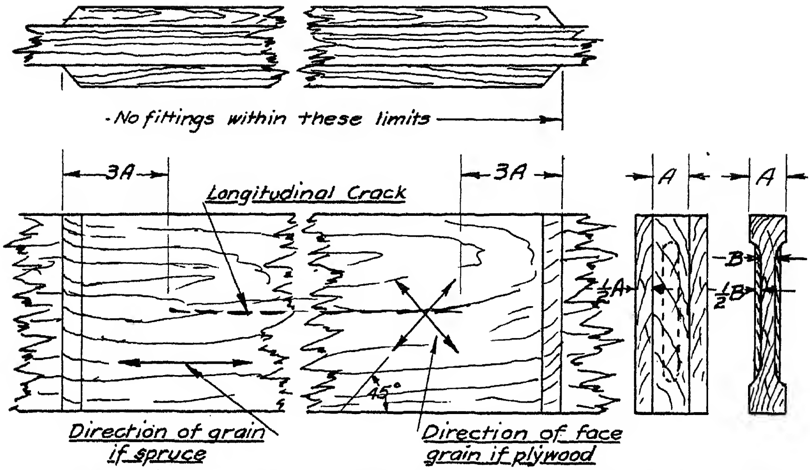


Plate thicknesses are for spruce. If plywood plates are used thickness may be one-half that specified for spruce.

FIG. VII - METHOD OF REPAIRING LONGITUDINAL CRACK

When it is necessary to splice a section onto a beam which is already assembled, a condition which often arises, the procedure illustrated in Fig. VIII is often useful. After cutting the two scarfs as accurately as possible, to insure a perfect fit the sections are put together and a strong, straight piece of two by four or similar material is clamped to both pieces. A saw is then run through the joint as shown and after sawing all the way through, the outer portion of the beam is tapped on the end until it will go no further, after which the saw is run through again. This is continued until the joint is perfect, after which both sections are carefully planed smooth and glued together. Unless the saw makes an exceptionally smooth cut, it is necessary to plane off the roughness, but a very light cut should be taken so as not to affect the fit.

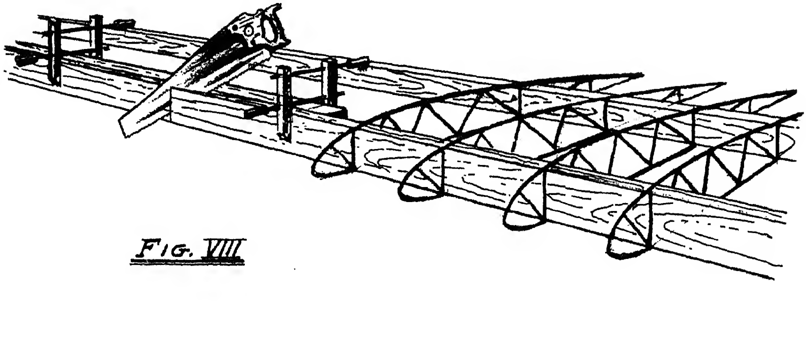


FIG. VIII

WING TIPS AND WING TIP BOWS

The wing tip is not simply the "stopping place for the wing." The efficiency of the airfoil, that is, its lift in proportion to its drag, is affected to a marked degree by the shape of its tip, as are also, to some extent, the stresses in the spars.

Probably the most efficient tip is the elliptical, such as is shown in Fig. I. Unfortunately, this is the most difficult and expensive type to build, due to the large number of special ribs required and the care which must be used in fairing the standard section down to the wing tip bow.

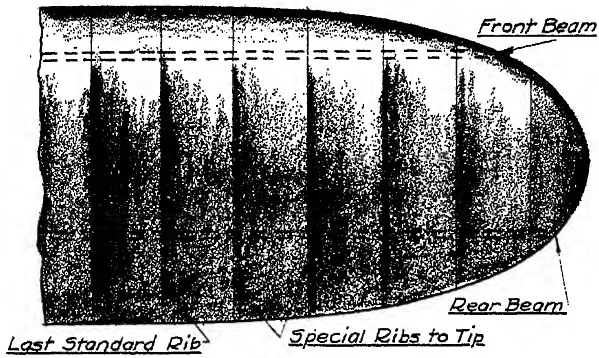
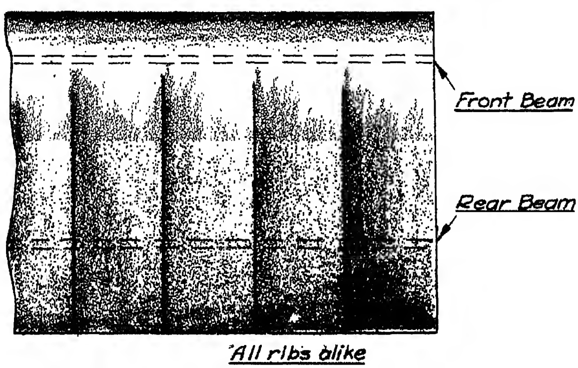


FIG. I

The most inefficient type is that in which the end of the wing is cut off square, as shown in Fig. II. This is done only on slow ships, which are designed to be built at a minimum cost. It is of course the simplest and cheapest to build, as there are no special ribs, no tapering of the beam, and no wing tip bow involved.



WING TIPS AND WING TIP BOWS
(continued)

There is a compromise, however, which calls for not more than one, if any special ribs, is good looking and almost as efficient as the elliptical. It is shown in Fig. III.

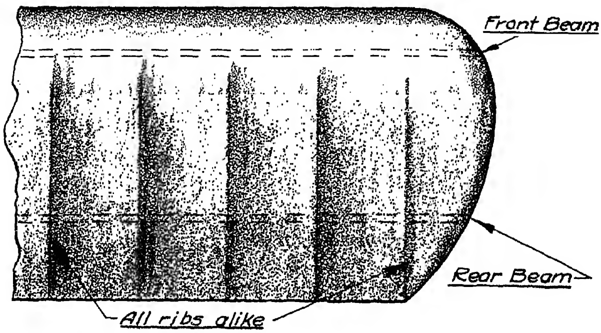


FIG. III

Wing tip bows are made of laminated wood or tubing. If the latter, either steel or dural may be used, the dural in most cases being lighter. The bow must be strong enough to withstand the pull of the fabric, to take such air loads as may be imposed upon it, and, especially on lower wings, to stand up under a certain amount of abuse, such as turning the ship around on the ground, dragging in a bad landing etc.

On large, metal covered wings, the bow is usually a half round section of sheet metal to which the covering is rivetted.

On the following page will be found instructions for laying out a wing tip bow.

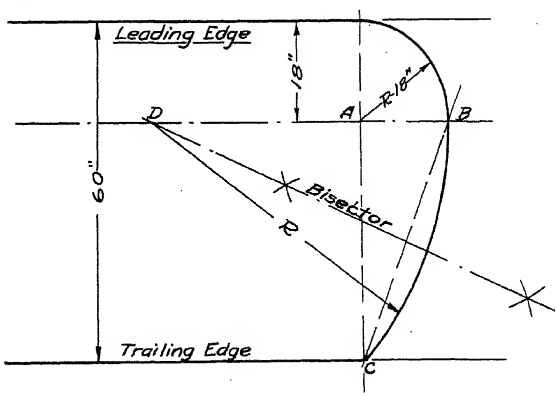
HOW TO LAY OUT A WING TIP BOW

On the preceding page, a shape for the plan form of the wing tip was shown (Fig. III) which was suggested as an excellent compromise between the elliptical and the square. By following the instructions given below, it will be found very easy to lay out this type of wing tip bow.

If the rib spacing for the rest of the wing is approximately 15", the bow should extend from 18" to 20" beyond the last rib. This eliminates any special ribs. The layout shown in Fig. I is made for a chord of 60", since all the other wing work so far taken up has been based on that dimension.

To make the layout, begin by drawing on a large sheet of paper two parallel lines 60" apart, representing the leading and trailing edges of the wing. At a point more than 18" from the edge of the sheet,(if it is decided to make the bow extend 18" beyond the last rib) draw another line at right angles to the two already laid out. This represents the outer edge of the last rib. Make a point on this line 18" in from the leading edge. Through this point, draw a line parallel to the leading and trailing edges, and extending to the edge of the layout sheet. Using the point (marked A on the diagram below) as a center, with a radius of 18" draw an arc, cutting the last line drawn at point B. Draw line BC. Bisect line BC as instructed under Simple Layout Problems in this book. Extend bisector to cut intermediate line at D. Using the point D as a center and with a radius equal to DB, draw arc BC, which will complete the layout of the wing tip.

The curves just completed represent, of course, the outside of the wing tip bow, or the extreme end of the wing. In laying out the bending form, as described in the following sheets, the same center points will be used, the radii simply being decreased by an amount equal to the thickness of the bow, so the sheet of paper with this layout on it should be preserved. In order to have the radii exactly tangent to each other at the point B, great accuracy is necessary in the layout. However, it is not difficult, in case the point D is slightly off, to "feel around" for the center along the line DB until the correct point is found.



HOW TO MAKE THE WING TIP BOW JIG

The wing tip bow for the model wing section is designed to be made of 3/4" laminated spruce, having six 1/8" laminations. In order to make this bow, it is necessary to first make a jig of the correct curve and also to provide means for clamping the bow while the glue dries. For this reason it is essential that the layout be the exact curve desired and that provision is made to clamp the bow while it is in this position.

The jig described below is a simple, easily constructed type and is for that reason widely used where the mechanic desired to make a jig that is to be used only once or twice.

MATERIAL: Supply of wood for blocks, box of 1-1/2" x 10 wood screws (nails may be used).

TOOLS AND EQUIPMENT: Layout drawing, large bench or other flat surface, wood tools for shaping blocks, screw driver, hand drill and correct size drills to drill holes for wood screws.

PROCEDURE:

1. Transfer the wing tip layout to the base selected for the jig. See rib jig construction.

2. Cut a number of blocks to 3/4" x 2" x 3", Fig. I.

3. Dress one end of the blocks to fit the inside layout line, Fig. I.

4. Screw the blocks into position, about 2" apart as shown on the drawing below, Fig. II.

5. Check the jig to make sure that all blocks are in the correct place to make a true curve.

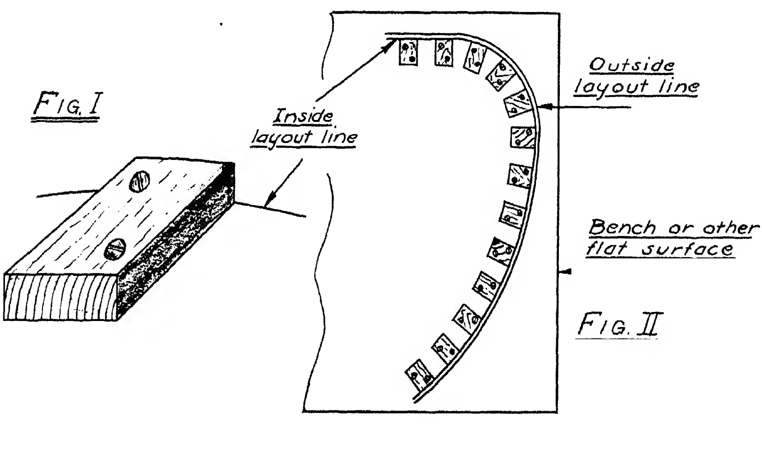


FIG. I

FIG. II

HOW TO MAKE A LAMINATED WING TIP BOW

MATERIAL: 6 Spruce strips, 1/8" x 3/4" x 8'; strap iron, 1/16" x 3/4" x 8'; casein glue; sandpaper.

TOOLS: Hand clamps, template, block plane, scraper.

PROCEDURE:

1. Place the six strips together to make sure all faces fit nicely.

2. Mix a quantity of casein glue, sufficient to glue 5 faces of the strips.

3. With a soft brush spread the glue evenly over all inside faces of the strips.

4. Place the strips together, making sure the edges are even, and place the strap iron on the outside and clamp to the first block on the front or largest curve of the jig. See Fig. I.

Note: Paper should be placed under the strips to prevent them from sticking to the base of the jig.

5. Carefully and slowly bend the strips around the curve and clamp to each block.

Note: It is better to have all the clamps adjusted to approximately the correct opening before starting to bend the strips, and then have them applied by an assistant as quickly as the strips come in contact with the blocks.

6. After 24 hours, remove the bow from the jig.

7. Prepare a template of pyralin, or stiff metal, to be used in dressing the bow, Fig. II.

8. Dress the bow to the template, using the block plane and scraper.

Note: Make sure that the template is always held at right angles to the bow, and that when finished, the bottom edge of the template and the bow are even.

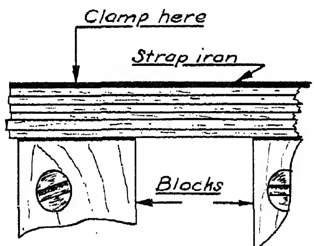
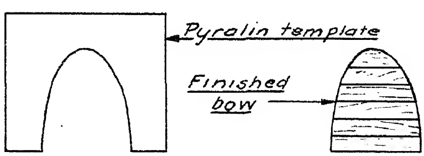


FIG. I

9. Sand the bow thoroughly, making sure that no bumps or hollows remain.

10. Check the bow thoroughly to make sure that all strips are tightly glued. If any strips are open, thin glue can be run in and the bow re-clamped. The bow is now ready to be fitted in the wing.



BENDING WOOD

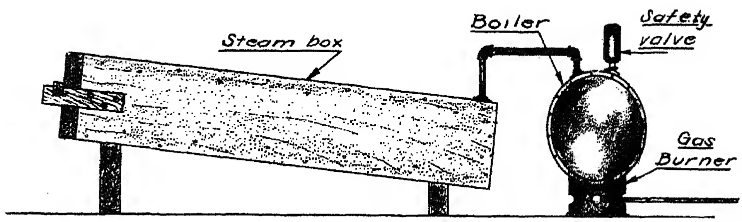
It is often necessary for the airplane mechanic to bend wood for such places as the keels of flying boats, wing tip bows, chines, fillets, ribs, etc., where it is more desirable to use solid than laminated wood. In selecting wood for bending, much care and judgment must be exercised to select only the best clear, straight-grained material. This material should be air dried, as kiln drying has a tendency to make the wood brittle. Ash, hickory and oak are usually used for bending as each of these woods is strong and tough and will hold a bend.

Soaking the wood in water before bending is done frequently where a simple repair is being made, as it requires no special equipment. To soak the wood, simply place in water the portion of the material to be bent. Let it remain there for a period of time, depending upon the temperature of the water, the material used, and the sharpness of the bend required. For instance, to make a slight bend in soft wood, only thirty minutes to an hour of soaking is required.

Steaming wood is a more satisfactory preparation for bending than soaking, as there is much less possibility of steamed wood breaking. Steaming wood thoroughly softens all the wood fibers, allowing it to bend readily and since it is hot, it dries quickly. One of the greatest disadvantages of steaming wood is that it requires a special steam box. By exercising a little ingenuity however, one can be made that will answer the purpose. In steaming wood the material is usually given one coat of boiled linseed oil, is then placed in the hot steam box and allowed to remain there from two to four hours. Sometimes the wood is removed from the box at the end of two hours, given the second coat of linseed oil and is then replaced in the box to remain for two more hours. This is necessary only where heavy material is to be bent. Of course, if any gluing is required, linseed oil must not be used.

Material should never be placed in the steam box before the box is filled with wet steam, for when the box is heating, the hot air has a tendency to dry out or even scorch the wood. Steaming wood for over four hours seems to take the life out of the wood.

In bending the soaked or steamed wood, a jig must first be made that has from 10% to 20% greater curve than the curve desired. This is done because the wood straightens that much as it dries.



SIDEWALK REINFORCEMENTS

The lower wings of biplanes must be provided at the butt end with a walk to allow passengers to get in and out of the ship and also to provide a place to stand when working on the plane. Sometimes this walk is on the left wing only, as the cockpit door is usually on that side, sometimes there is a wide walk on the left and a narrow one on the right and sometimes there is a wide walk on both wings, which is the best arrangement from the standpoint of service, though it naturally increases the weight somewhat.

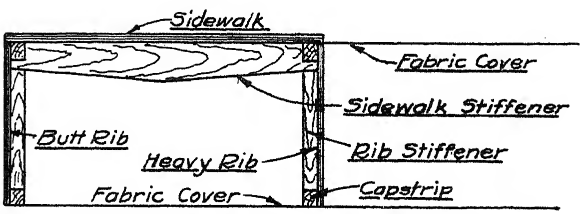
Since the sidewalk must withstand the concentrated weight of a heavy passenger and often two passengers, it must be made quite substantial. As a rule, the two inner ribs are made with solid plywood webs and the top surface of the wing is covered with plywood, usually about 3/16 thick, either under the fabric or on top of it, though sometimes the fabric ends where the walk begins. The walk is usually covered with ground cork or flint to prevent slipping and wear. This will be taken up further under Covering.

The face grain of the plywood cover should, if possible, run parallel to the wing beams for two reasons. First, the plywood will bend to the contour more easily and second, it is stronger when applied in this manner.

The thickness of the plywood may be reduced if small spruce stringers, approximately 1/2"x 1", are run between the ribs at intervals of six to eight inches, though of course this adds to the labor of building the wing.

In any case, great care should be taken to make the sidewalk structure amply strong, for if it breaks while a passenger is on it he tends to lose confidence in the ship and furthermore, it means a rather nasty repair job.

The sketch below indicates a typical sidewalk installation with heavy ribs and reinforcing stringers. The view is of a lengthwise section of the wing cut parallel to the spars.



Longitudinal Section at Inner End

FUSELAGE FAIRING

Early airplanes carried their empennage on an exposed skeleton framework, but it was soon found that this caused a large amount of resistance as well as providing no protection for the occupants of the ship.

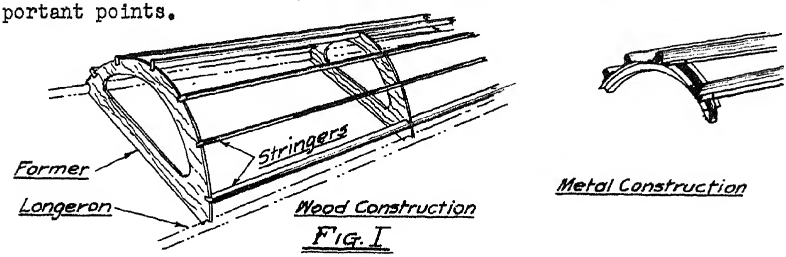
The modern plane has a fuselage which is either a metal monocoque or a steel tube frame covered with fabric held to the proper shape by fairing strips and formers. The latter type predominates at present and is the one with which this sheet deals. Metal monocoque construction is taken up under Metal Work.

Unless the covering is used to carry the loads imposed by the tail surfaces, landing shocks and the other stresses to which the fuselage is subjected, cloth is by far the most satisfactory material that can be used. It does not dent like metal, is relatively cheap, easily put on, easily repaired if damaged, and with the proper methods can be given as fine a finish as an expensive automobile.

In most cases it is not satisfactory to have the cloth supported by the longerons alone as they are placed so as to carry the loads in the most efficient manner without great regard for streamlining. To improve the aerodynamic properties of the fuselage as well as, in many cases, to give more room for the passengers, the fabric is carried on longitudinal members, usually called stringers, which in turn are held up by curved pieces of wood or metal known as formers. The stringers may be made of narrow strips of wood or of U-shaped pieces of dural. The stringers should project beyond the formers so as to keep the fabric from touching the latter, as this would cause a ridge across the line of air flow. Illustrations of the wooden type of construction will be found in Fig. I, while the metal is shown in Fig.II.

The complete section of fairing on top of the fuselage from the cockpit to the tail is often called the "turtleback" and is sometimes made so that it can be removed in one unit to allow inspection or repairs on the inside of the fuselage.

Around the cockpit, in the case of an open ship and around the engine in all ships, the fairing or covering is aluminum or duralumin well supported by formers or diaphragms as they are sometimes called. While the metal is much heavier and more expensive than cloth, it is, of course, fireproof, and if properly supported and of sufficient thickness, much stronger and more able to take abuse than fabric could ever be, and for this reason is used at these important points.



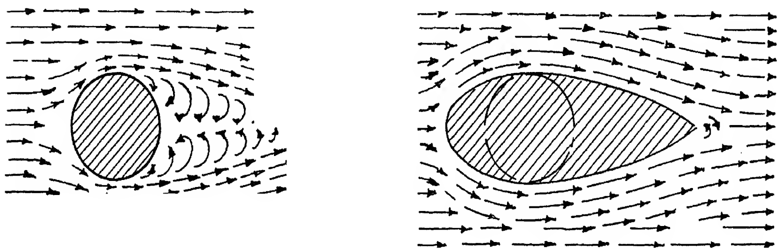
Wood Construction

Metal Construction

FIG. I

STREAMLINE STRUTS

A glance at Fig. I will show the derivation of the word "streamline". When a round bar is moved through the air, there are eddies and a partial vacuum behind it which causes a high resistance. By filling up the space behind the bar with a shape fitted to the lines of the air stream, the eddies and vacuum are eliminated and the resistance is reduced to less than one-tenth of that of the round rod. This streamlining is commonly called fairing.



indicate flow of air

In proportion to its weight, a round tube is the strongest shape for compression loads. Furthermore, it is sometimes desirable for other reasons. When it is necessary to expose a round tube to the air stream, in such cases as external fuel lines or landing gear axles, it is often faired by one of the methods shown in Fig. II.

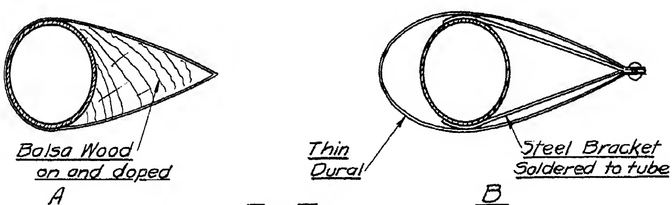


FIG. II

Sometimes when wood fairing is used as in A, a nose piece is added to make a complete streamline section like the one in B.

STREAMLINE STRUTS
(continued)

The ratio of length to thickness or L/D in Fig.III is known as the "fineness ratio". The ideal section for the ship of average speed has a fineness ratio of about 3.5. The faster the ship the higher this should be.

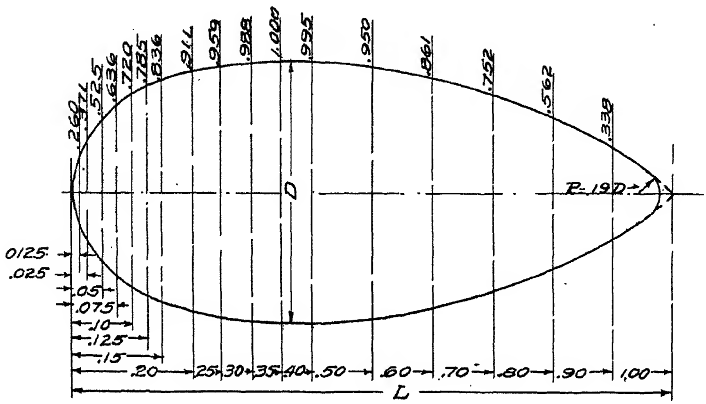


Fig.III

The ordinates and abscissae given in Fig.III may be used for any fineness ratio as the distances from the nose are given in per cent of L and the widths in per cent of one-half of D. Half of D is used so that the curve may be laid out directly from the center line, using the figures obtained without having to divide by two.

Until a few years ago it was impossible to obtain tubes in streamline shapes. Now, however, streamline tubing of either duralumin, mild steel or alloy steel may be obtained from any aeronautical supply house and is used practically exclusively for all exposed struts. While it is slightly heavier than round tubing faired with sheet metal or wood, it is cheaper, since there are no fairings to make up, and much more serviceable, as fairings, due to their lightness are easily damaged. Streamline tubing is made in accordance with the curve shown in Fig.III, usually with a fineness ratio of about 2.5, for if it were made narrow in proportion to its length, the ratio between the strength and the weight would be too low. Also, instead of coming to a point at the rear, there is a radius (shown by the dotted line) of .19D. A sharp corner might crack and would be harder to make.

Further information on streamline tubing will be found under Metal Work.

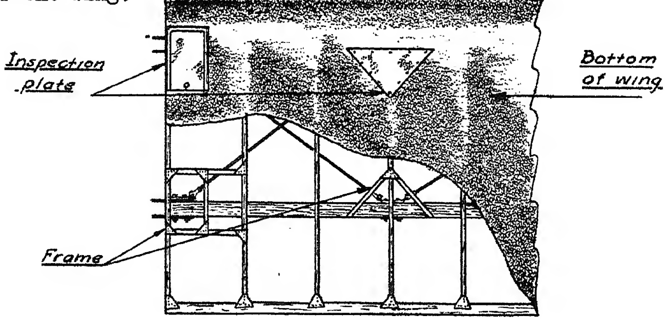
INSPECTION PLATES

It is necessary to inspect periodically points on the interior of the wing, such as hinge fittings, aileron control pulleys, drag trussing, electrical connections, air speed indicator connections, etc. To do this there must be an opening in the cover and if no provision is made for this inspection, an opening must be cut in the cover whether it be fabric or plywood. It can be readily seen that if an opening must be cut and consequently repaired each time an inspection is made, much inconvenience would be caused and much time lost. For this reason it is customary to place an inspection plate, or cover, at such points as the ones mentioned above which require frequent inspection.

There are several types of inspection plates, but their general purpose is to provide an easily and quickly removable and replaceable cover for inspection purposes. This is very often done by attaching a dural frame on top of the fabric or skin, to a wooden frame which has been built underneath the cover. This frame is closed on three sides, the fourth side being open to allow a dural or pyralin plate to be slid into the frame and fastened with one screw or cowling fastener to prevent its coming out in the air. Some plates, made to cover a less frequently inspected point, are made simply by placing a wood backing underneath the cover and fastening a plate to the backing with several flat head wood screws. Pyralin would seem to be the ideal material for covers as it permits visual inspection of the parts without removing the plate. If pyralin is used, however, the cover must be replaced frequently as it turns yellow with age.

Although inspection plates are made to cause as little skin friction as possible, it is slightly better to place them on the bottom camber of an airfoil, as they interfere with the lift to a lesser degree. In some cases it is desirable to place the cover in the top camber and when this is done the cover is usually made with a waterproof fit, especially on seaplanes. This is usually accomplished by setting the cover plate in heavy grease and fastening it securely with screws.

In the wing pictured below inspection plates of two types are shown. The plate at the hinge fitting is of the sliding cover type, and the one at the compression rib is fastened with wood screws. The frames for these inspection plates are illustrated on the lower half of the wing.



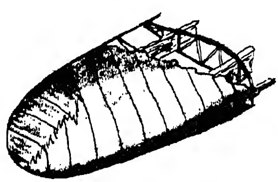
PLYWOOD WING SKINS

In certain special types of airplanes it is found desirable to cover the wings with some material other than cloth. For example, in extremely fast ships the ribs would have to be so close together and the nose fairing have to extend so far back that it is just as cheap and light to cover the whole wing with plywood. Another instance is the large cantilever wing, which if covered with cloth may show a tendency to warp and produce wing flutter, as a cloth cover adds practically nothing to the strength of a structure. If the main structure of the wing is metal, it is logical, if cloth is not to be used, to make the cover or "skin" of metal also. If on the other hand the framework is wood, it is usually desirable to use plywood for the skin. When this is done, the skin is usually made to carry the drag loads and the usual drag truss eliminated, provided the fastenings between the skin and the spars and ribs are properly made.

Before the plywood cover is put on, the positions of all the members to which it is to be glued should be laid out carefully with a pencil so that no varnish will be applied on these areas. (See "Protection and Finishing of Woodwork"). Putting on the skin is no job for a poor mechanic as the most careful sort of work is necessary. The center lines of all members of the structure should also be marked on the outside so that the nails or screws which are used for fastenings may be put in the proper places.

The plywood used for the skins is usually comparatively thin and since it is put on in rather large sheets it often shows a tendency to warp and buckle between supports. This can be eliminated to some extent by using plywood made entirely of spruce instead of the more usual type which has a hardwood face and a soft core. The all-spruce will buckle if exposed to moisture for extended periods but will straighten out again when it has an opportunity to dry thoroughly, whereas the other kind will remain buckled. Needless to say, the greatest care should be used in protecting the surface. (See "Protection and Finishing of Woodwork").

Sometimes in the case of small wings for racing ships the plywood is built up directly on a form of the wing. This is by far the best method as the sharp curves of the leading edge are built right in and there is no tendency for the skin to straighten out. However, the procedure is very expensive as an accurate, solid form of each wing must be built and one lamination put on at a time and glued and tacked in place. The laminations are usually laid on in thin strips two or three inches wide with the grain of the adjoining plies at 90° to each other. See sketch below.



Built-up plywood wingtip

PLYWOOD PATCHES

There are many times when it is desirable to repair small holes or punctures in plywood, rather than replace the entire panel. This may be done by putting a patch over the damaged area, in one of the three following methods.

THE EXTERNAL PATCH

This patch is probably the easiest patch to make, but its use is confined, as a rule, to very thin plywood and to internal panels such as bulkheads, nose fairings, etc. To repair a hole with this type patch, first remove the jagged edges of the hole by cutting away enough material to make it into a standard shape, round, square or rectangular as shown by the dotted lines in Fig. I.

Fig. I   Fig. II   Fig. III

A patch is then cut of the same material and thickness as the original panel, large enough to extend at least 3/4" over all sides of the opening, or in the case of Fig. II, the patch has a 1-1/2" larger diameter than the hole. This patch then has the edge feathered, or tapered down to avoid protruding corners, Fig. III. In gluing an external patch, it is nearly always impossible to use clamps, so the pressure can be supplied by blocking up the bottom of the panel and placing a heavy sandbag on the patch until dry. The patch should be held in place with two or three small nails to prevent slipping.

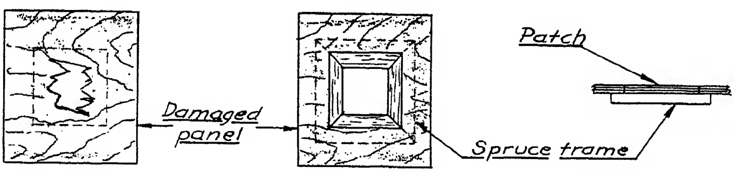


Fig. IV   Fig. V   Fig.

THE FLUSH PATCH

In places where an external patch would be objectionable, on wing coverings or fuselage skin, etc., a flush patch is used. To make this repair, the damaged area is first trimmed to a definite square or rectangle, using great care to keep the edges of the plywood square and straight, Fig. IV.

PLYWOOD PATCHES
(continued)

A frame is then made from 1/4" spruce, 3/4" or 1" wide and is glued under the opening in such a manner as to provide a 3/8" or 1/2" bearing for the patch, Fig. V. Where possible, small clamps should be used to glue the frame in place, and small flat head wood screws spaced about 1" apart should be used to further reinforce the frame. The patch is of the same material as the panel and is made to fit the opening exactly. The patch is now glued in place with small wood screws or nails as reinforcements.

THE SPLAY PATCH

While the splay patch can be used to repair small areas, it is seldom done as it is a difficult patch to make correctly and unless made very carefully, is no stronger than the flush type patch. This patch is usually used only in replacing a large damaged area where the opening can be trimmed back to structural reinforcements such as spars, ribs or stringers, Fig. VIII.

The edges of the panel are then carefully chiseled to as nearly as possible a 10-1 taper. A patch is then made to fit this tapered or splayed opening and can be securely glued and nailed into place.

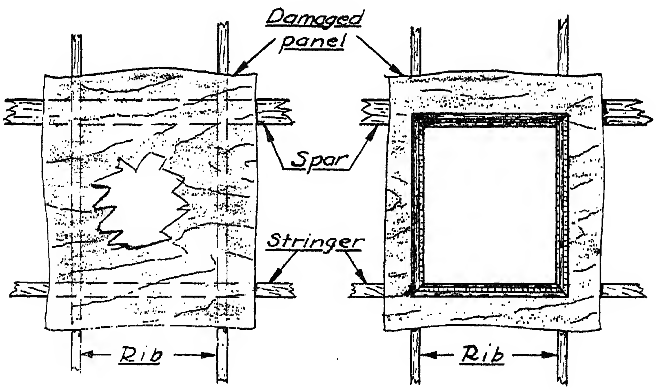


FIG. VII FIG. VIII

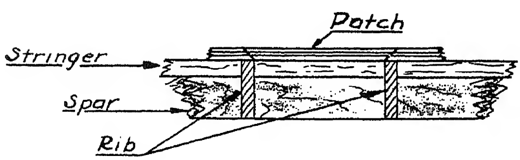


FIG. IX

WOOD SCREWS AND THEIR USES

With the present trend toward all-metal construction the use of wood screws has become rather limited. However, they are still used for some purposes in nearly every airplane built, consequently the mechanic should be familiar with their application and use.

In addition to the types of wood screws described below, there is the Phillips head screw which is similar to the others except that it has an 'X' slot in the head instead of the usual slot. Although the Phillips head requires a specially ground screwdriver it is considered desirable by many manufacturers.

To answer a great variety of purposes, wood screws are made of four different materials. Steel wood screws are the strongest and also the least expensive, and for this reason they are used where strength or economy is of major importance. Although brass wood screws are somewhat more expensive than steel, they are widely used as they do not rust. Where it is necessary to use wood screws in aluminum sheets, an aluminum alloy screw should be used. Brass screws which are in contact with aluminum will cause a harmful chemical reaction resulting in the rapid deterioration of the aluminum.

WOOD SCREW HEADS

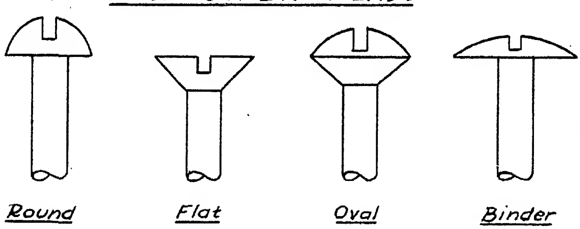


FIG. I

Wood screws are furnished with four types of heads, Fig. I. In general, their uses can be determined by the finish desired, however to be more specific, their use is determined by the material to be fastened. The round head wood screw is used in thin material such as sheet metal or plywood, as it does not require countersinking. The flat head screw is used where a flush finish is desired and where the material is thick enough so that countersinking does not impair its strength. The oval head screw is used quite frequently in cabin trim etc., as it presents a somewhat neater appearance than does either the round or flat head screw. The binder head screw is used in such places as metal covering of hulls, etc. where a round head screw would cause too much resistance, and where the material is too thin to countersink.

Wood screws are designed to cut their own threads as they are driven into wood with a screw driver. They derive their holding power from the threads they cut in the wood, therefore it is essential for the screw to be driven properly. To drive screws properly, guide holes should be drilled for every screw. Fig. II illustrates the use of the guide hole. The first hole is drilled as a clearance hole for the shank of the screw. This hole should be as nearly as

WOOD SCREWS AND THEIR USES
(Continued)

possible the exact size of the shank, for if it is too large it will allow the top member to shift, throwing an undue load on the screw head. If the clearance hole is too small, the shank will bind so tightly that the threads cannot "pull" the screw into the wood. If the screw is driven by putting an extra amount of down pressure on the screw driver, the screw will enter so slowly that the threads will ream out the second hole rather than cut holding threads.

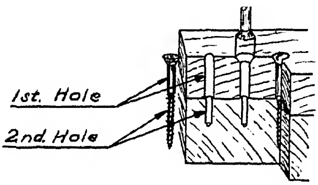


FIG. II

The second hole must be of the correct size to allow the threads to get a full grip in the wood. When this hole is too large the threads will not hold, for all the wood necessary to provide the holding grip is removed. An excessive pressure is required to drive the wood screw if the second hole is too small. This additional pressure often causes the screw to be twisted in half, or causes the wood to split. If the second hole is not long enough, the screw then has a tendency to hold the members apart, or at least to prevent them from being drawn together tightly.

After the guide holes have been drilled to the proper size, they are then countersunk, if a flat or oval head screw is to be used. A regular wood countersink should be used for countersinking. Metal twist drills should not be used for this purpose, as they do not provide the correct angle. A drill is ground to an angle of about 60°, whereas the angle of a wood screw head - oval or flat - is 80°. It is better to stop the countersink slightly under the size needed, to allow the screw to pull down into the wood to a slight extent.

The correct size drills for the first and second guide holes will be found on the chart below. The sizes of the drills for the first or clearance hole are given in the decimal fraction as well as the number size. It is recommended that a somewhat larger drill be used in hardwood than in soft wood.

Number of Screw	Diameter of Shank	Diameter of Head	Clearance Drill		Second Hole Hard Wood		Second Hole Soft Wood	
			No.	64ths	No.	Decimal	No.	Decimal
1	.071	.137	48	5/64	56	.046	60	.040
2	.084	.163	44	5/64	54	.055	56	.046
3	.097	.189	40	3/32	51	.067	53	.059
4	.110	.216	33	7/64	47	.078	50	.070
5	.124	.242	30	1/8	41	.096	43	.089
6	.137	.268	28	9/64	36	.106	39	.099
7	.150	.295	24	5/32	32	.116	36	.106
8	.163	.321	19	11/64	29	.136	30	.128
9	.176	.347	16	11/64	26	.147	28	.140
10	.189	.374	12	3/16	20	.161	23	.154

DRILLING WOOD

The drilling of wood members for fittings requires great care and precision, as it is quite easy to endanger the strength of the material by making the hole oversize. Two of the most common mistakes are shown in Fig. I. In the top holes, the bolt hole was drilled half way from each side, but failed to meet in the middle. If an attempt were made to remedy this condition by reaming out enough material to make a continuous hole, a large hollow space would be left in the interior of the beam. This takes away the bearing surface for the bolt, allowing it to bend. Looking at the bottom hole in Fig. I, it will be seen that the hole was drilled from one side only. This is the correct method, but if this is done extreme care must be used to hold the drill at exactly the correct angle, or the result will be as shown. Any attempt to align this hole will result in the elongation of the hole at the fitting. This would allow the fitting to be pulled out of place.

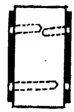


FIG. I

The really dangerous part of drilling holes incorrectly is that after the fitting is bolted in place, it is impossible to inspect the condition of the holes. This is such an important point that the Bureau of Air Commerce will not allow the field mechanic to drill holes for such important fittings as the hinge fittings, etc. This must be done at the factory or an approved repair station.

When boring with a wood bit, the hole should not be bored entirely from one side, as the bit will split out the opposite side when it breaks through. This can be prevented by stopping the bit as soon as the point shows on the opposite side, then placing the point of the bit in this small hole and finishing the cut from the opposite side.

Although it is customary to drill wood using a wood bit, it is sometimes more convenient to use a metal twist drill for the smaller holes. This is especially true when drilling guide holes for wood screws. If many holes are to be drilled with a twist drill, it will be found worth while to resharpen the drill to a sharper angle, as it will cut faster. Where a great number of guide holes are to be drilled, the following method has proved to be of great convenience. Select a twist drill slightly smaller in diameter than the shank of the screw and grind the drill so that it has the same taper as the screw, Fig. II. This is an unusual practice, but a few trials will convince you of its usefulness.

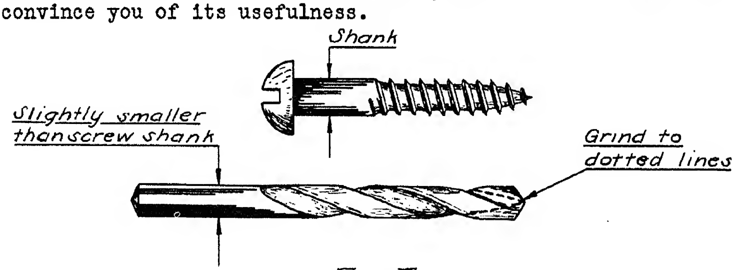


FIG. II

PROTECTION AND FINISHING OF WOODWORK

Aside from the desirability of having wooden structures present a finished appearance, it is essential that the proper moisture content of wood be maintained because of the effect it has upon the strength, as pointed out in the section on woods. The only way this can be done is to seal the surface so that it is difficult for moisture to get either in or out. This applies whether the wood is inside a covered wing or not, as there are always vent holes in any covered surface to permit the air to pass back and forth with changing air pressures.

For woodwork which is finished purely from the standpoint of protection and not for decorative purposes, a satisfactory procedure is to apply with a brush one coat of liquid wood filler and two coats of spar varnish, taking care to work into all corners and allowing ample time between coats for drying. An excellent filler is sold under the trade name of "Lionoil". Boiled linseed oil makes a good first coat but dries rather slowly. Shellac should never be depended upon for real protection as it does not penetrate the fibers to any extent and breaks down quickly when exposed.

Of course, no finish should be applied on any surface which is later to be glued. In such cases as the inside of plywood webs of box spars, the areas which are to be glued should be carefully marked out with a pencil and the finish put on with a small brush so as not to run over the lines. The same applies to plywood wing skins or any other type of structure in which the inside cannot be finished after assembly. This is highly important.

When a surface is to be in contact with fabric which will er be doped, a coat of dope proof paint should be applied over the final finish, as the thinner used in dope will dissolve any varnish or lacquer and destroy the effectiveness of the protection.

If the woodwork to be finished is exposed, such as cabin trim, instrument boards and the like, it is necessary to go further than simply protecting the moisture content. In fact, in these cases strength is usually unimportant, appearance being the prime consideration. The surface should be planed smooth, if possible, and if not, sanded with No. I sandpaper. This should be followed by a thorough sanding with No. 2-0 or 3-0 paper. If it is desired to darken the color, a suitable stain should be used, followed by a paste wood filler of the proper shade. It may then be very lightly sanded with the finest sandpaper available and more paste wood filler applied.

This should be followed by two or three coats of varnish, sanding each coat except the last one, and putting on the varnish in a location as free from dust as possible. The last coat may be sanded with No. 380 wet-or dry sandpaper, following this treatment by rubbing with powdered pumice and oil or rotten stone and oil. This will give a glossy, permanent finish, which is also as good a protection as could be desired. Further information on the application of lacquer will be found in section on painting.

BUILDING A WING PANEL

For the purposes of practice and familiarization with the proper procedure, it is considered highly desirable for the student mechanic to build the parts and assemble the outer portion of a wing. While the instructions below apply specifically to a section about six feet long, the panel may be made any desired length, if material is available, by making the beams longer and putting on more ribs and drag bays.

Instructions for making the necessary fittings are given under metal work, and if it is desired to cover the panel, directions will be found under fabric work. The same applies to doping and finishing. The parts necessary for making the wing are listed below, together with the title of the sheet which gives instructions for making them.

Part	No. Req.	Title of Sheet
Rib (standard)	3	HOW TO BUILD A TRUSSED TYPE RIB
Rib (root)	1	RIBS USED AS COMPRESSION MEMBERS
Beam (front)	1	HOW TO MAKE A BUILT-UP I-BEAM
Beam (rear)	1	" " " " " "
Tip Bow	1	HOW TO MAKE A LAMINATED WING TIP BOW
Hinge Fitting	2 Sets	HOW TO MAKE A HINGE FITTING
Drag Fitting	2 "	HOW TO MAKE A DRAG FITTING
Leading Edge	1	HOW TO MAKE A LEADING EDGE STRIP
Trailing Edge	1	TRAILING EDGE STRIPS
Drag Strut	1	RIBS USED AS COMPRESSION MEMBERS

The drag strut is simply a piece of 3/4" O.D. steel or dural tubing. The necessary bolts, nuts, screws, cotter pins, etc, are not included as the quantities may easily be estimated from the detail drawing. It is advisable to use aircraft bolts and nuts but if they are not available, ordinary machine bolts may be used. The latter is bad practice, however, as it tends to give the student false impressions. Of course, the use of any but aircraft material is absolutely prohibited in work on anything that is to be actually used in an airplane.

The type of root rib preferred for this particular job is made with a solid web, spruce capstrips, and spruce compression member of the dimensions shown on Fig. I. Note that the capstrip and compression piece is on one side only, so that there are no parts projecting beyond the inner end of the wing.

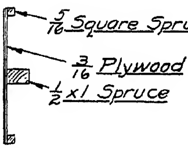
Having collected all the parts, two horses at least five feet long should be obtained, leveled, and nailed to the floor. A large table may be used in place of the horses but it is not as good. Blocks should be cut to hold the beams, as indicated in Fig. VIII, and fastened to the horses, taking care that the bottom of the front beam is enough higher than the bottom of the rear to make the chord line, or straight portion of the rib, level. The hinge fittings should be assembled to the beams and the beams set into the blocks. The three standard ribs should be slipped onto the beams from the tip end but not fastened. The root rib should now be put on and fastened permanently by cutting slots for the hinge fittings, gluing and nailing to the beam.

BUILDING A WING PANEL
(continued)

The next step is to assemble the drag fittings to the beams and put in the drag strut. Stretch light wire or cord from the pinholes in the drag fitting to the corresponding hole for the drag wire in the hinge fittings, and make sure that the wires clear the diagonal members of the ribs. The standard ribs may now be glued and nailed in place. See Fig. II for details of the joint between beam and rib. Next, assemble the leading and trailing edges, as shown in Figs. III and IV.

Cut a scarf at the outer end of the leading edge strip for the wing tip bow. This joint is shown in Fig. V, and the joint at the trailing edge is shown in Fig. VI.

It is desirable that aircraft tierods be used for drag wires, but if this is impossible, piano wire or cable and turnbuckles may be employed. The wing should now be trammelled and safetied after which it should be filled, varnished, and all surfaces in contact with the fabric painted with dope proof paint. (See "PROTECTION AND FINISHING OF WOODWORK"). After this has been done, the panel is ready for covering.



Section of End Rib
FIG. I

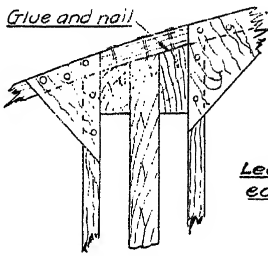


FIG. II

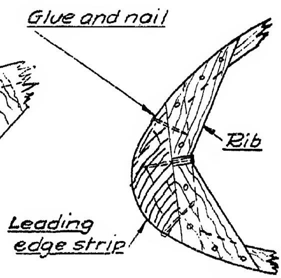


FIG. III

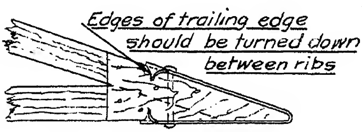


FIG. IV

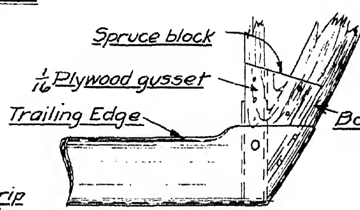


FIG. VI

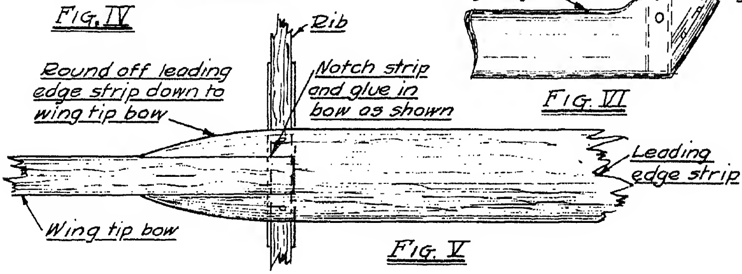


FIG. V

BUILDING A WING PANEL
(continued)

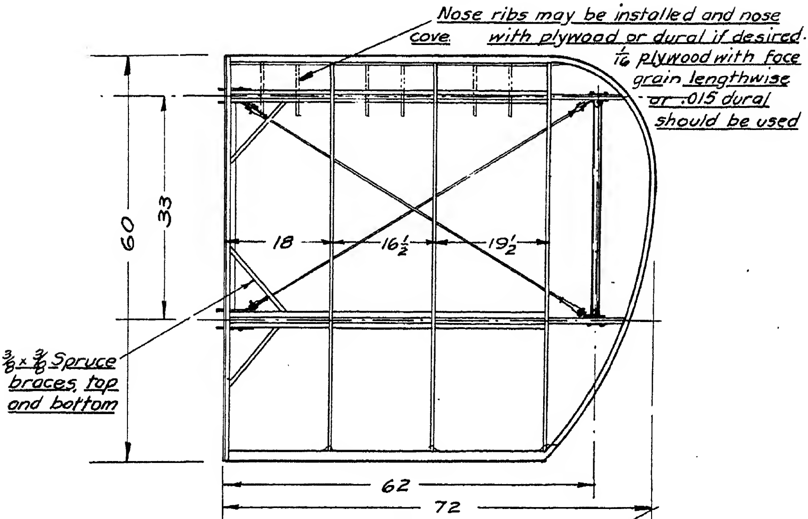


FIG. VII

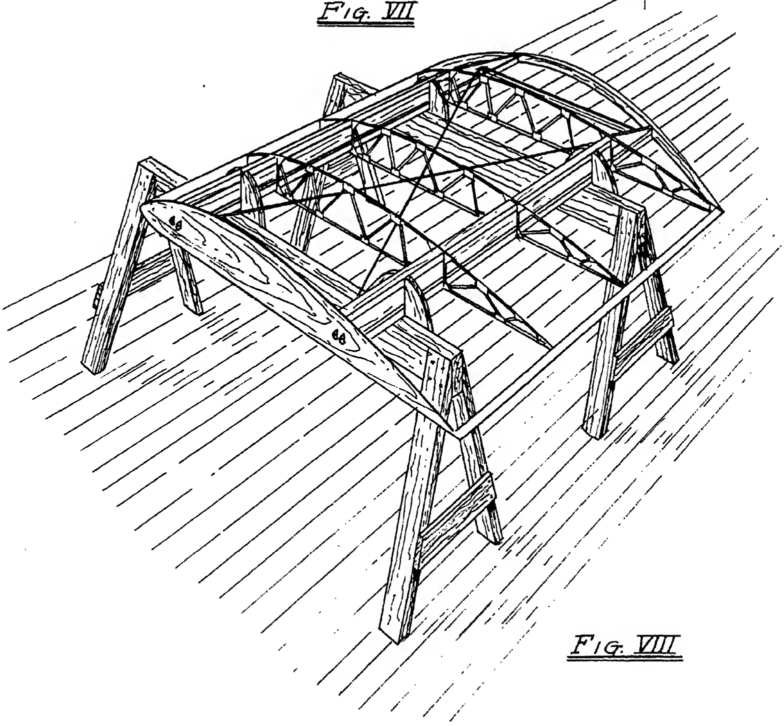


FIG. VIII

BUILDING A WING PANEL
(continued)

In practice covering, as in all other practice jobs, regular aircraft material should be used if possible. While it may seem that substitutes afford just as much opportunity for the development of the necessary skills, they are likely to give the student a false impression and cultivate habits of carelessness. In the specific case of covering, muslin may be used for example, but the effect of dope on this material and the method of application is not the same as if airplane fabric were used.

***

DURAMOLD

On the first page of this section is a photograph of the Clark "Duramold" cabin monoplane, powered with a 450 h.p. Ranger twelve-cylinder inverted Vee-type aircooled engine. The clean lines and smooth surface of this ship should be noted, for it embodies a type of construction which bids fair to give metal serious competition. In the introduction to this section, comments were made concerning wood as compared to metal, but the wooden construction referred to was of the conventional type, in which the wood is just as it comes from the tree, except for the drying process, and a certain amount of varnish or other protective coating. Duramold also is made of wood, but is a far cry from the old type of wooden construction.

Before going further, a brief and simple discussion of certain engineering principles is necessary. The strength of a beam or column depends not only upon the tensile or compressive strength of the material from which it is made, but also upon the dimensions of the cross-section of the member. In the case of a beam, the strength in bending varies as the square of the depth. Thus, in the beams shown in Fig. I, supported as indicated and loaded in the

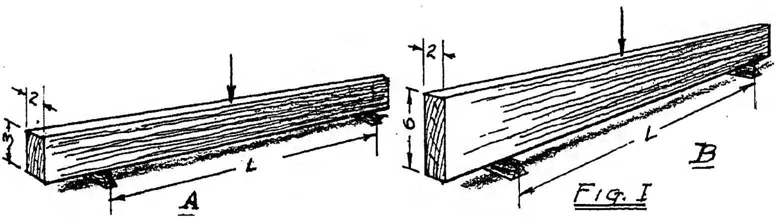


Fig. I

direction of the arrow, though (B) is the same width as (A) and only twice as deep, (B) is four times as strong as (A). It is for this reason that routed, box, and I-beams are used, namely to get the material as far from the neutral axis as possible. In the case of columns, or struts, the hollow cylinder, or tube, is the strongest section for its weight, for the same reason.

Obviously, since the beam (B) has the same width and length, and twice the depth of (A), (B) weighs twice as much as (A). But remember that, if made of the same material, (B) is four times as strong as (A). A moment's consideration will show that if the material used in (B) is only one-half as strong as that used in (A) and one-half as heavy, then (B) will weigh the same as (A) but will still be twice as strong as (A). The foregoing should be reread until it is entirely clear, for it is upon these facts that the principle of Duramold is based.

A piece of thin metal, such as aluminum alloy, may readily be fastened in such a manner that its full tensile strength can be developed. But under compression loads, it will buckle long before its ultimate strength (in lbs. per square inch) is developed. (See "Properties of Metals" in next section for a more complete discussion of ultimate strength). This statement is so obvious that it scarcely needs simplification. However, consider a strip of metal

DURAMOLD
(continued)

one inch wide, 1/16 inch thick and two feet long. If the material has a tensile strength of 48,000 lbs. per sq. inch, the strip will carry a load of 1" x 1/16" x 48,000 lbs. per sq. in. = 3000 lbs., in pure tension. But stand it on one end and put a load on the other, and what happens? It buckles under a load of only a few pounds.

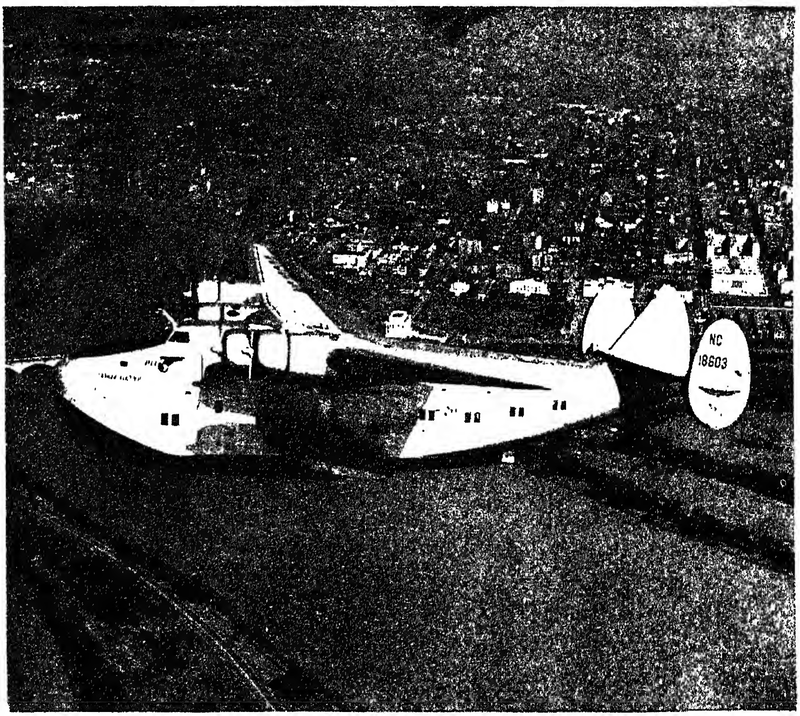
Now consider a piece of thin metal roller into a cylinder, such as a stove-pipe. This shape will carry much more than a flat sheet, but under compression will still buckle at a stress far below its maximum tensile strength. In order to make the material develop anywhere near its actual strength it must be prevented from buckling by means of stiffeners riveted or otherwise fastened to it, parallel to its longitudinal axis.

However, if the material, instead of being thin metal, were made of something much lighter, the thickness of the sheet could be correspondingly increased, without increase in weight. And since the cross-sectional area, or "bulk", would be much greater, this material could be capable of a lower unit stress (see "Properties of Metal") than metal and yet the structure made from it would be much stronger than the metal structure. Furthermore, no stiffeners would be needed, since the greater thickness of this material would prevent buckling.

Wood is such a material, but has many disadvantages, as, for example, ready moisture absorption, uneven texture, deterioration with age, etc. If wood were impregnated or saturated with some substance which would eliminate these disadvantages and yet not increase its weight unduly, plainly it would be an ideal structural material. Such a substance is Duramold, developed under the direction of Col. V. E. Clark and with the cooperation of the Bakelite Corp. and the Haskelite Corp.

The fuselage, and other parts, of the Duramold airplane are built on cast iron forms. The wood is put on in narrow strips, a method which permits a double-curved surface to be produced. Three layers or laminations are used and the plastic material is forced into the cells of the wood under a combination of heat and pressure. The resulting product has a surface which is perfectly smooth, it will not absorb moisture, will not support combustion, is not affected by climatic conditions, absorbs shocks well, and apparently does not deteriorate with age. The duramold fuselage has no stringers nor formers, the shell itself being strong enough to carry the loads which may be imposed upon it. Due to the absence of rivet heads and the perfection of the fairing, the air-resistance is 25% less than that of a metal ship built to the same lines. It is also lighter than the metal airplane. Last, but by no means least, it can be built in a small fraction of the time required for metal construction. In case of war or other emergency, Duramold aircraft could be produced with amazing rapidity, far beyond any yet seen in airplane production.

AIRCRAFT METAL WORK



THE YANKEE CLIPPER

All Metal Flying Boat
Built By The Boeing Aircraft Co.

INTRODUCTION

Every airplane is built partly of metal. Some use no other structural material - the so-called "all-metal" ships. The metals used for structural purposes (that is, to withstand loads) are limited in number, whether the ship is all-metal or not. In the sheet on "Properties of Metals" will be found the complete classification of the various kinds of metals together with their strength, weight, etc. For the present, it is sufficient to mention only the two main groups: steel, which is alloyed with small quantities of other material for various purposes, and aluminum, which is also used more widely in its alloyed form than as pure aluminum.

The tendency at present, as stated elsewhere in this book, is toward wider and wider use of metal. Metal has the advantage over other materials, particularly untreated wood, in being uniform in strength. That is to say, two pieces of chrome-molybdenum steel of the same specification and heat treatment will carry, within a fraction of a per cent, the same load and will have the same weight, whereas wood, even when most carefully selected, may vary five per cent or more in either strength or weight or both. Furthermore it is very difficult sometimes to make attachments to wood in such a way that its full strength can be developed, whereas this is very simple with metal. Wood, except in Duramold or similar compositions, will absorb moisture and increase in weight while the strength decreases. Metal is subject to no such fluctuations. If exposed to the elements without protection, wood will deteriorate just about as rapidly as metal, while with the proper protective coatings, metal will outlast wood and will not deteriorate for practically unlimited periods of time.

Metal lends itself to production methods much more readily than wood. It may be punched, stamped, rolled and formed where wood parts must be cut out of a solid piece. It may be joined by welding so that the joint is as strong as the rest of the material, where the only means of fastening wood parts together is by glue, which always leaves the strength of the joint open to question. Andwith the advent of "stainless" steel, which is so strong and stiff that even such parts as the sides of floats may be only eight one-thousandths of an inch thick, a new field of possibilities has been opened up. Sheets of this material may be fastened together by electric "shot" welding almost as fast as two strips of cloth are stitched to each other on a sewing machine. So with all these advantages, it is natural that all the more expensive ships are built of metal. For certain parts it will always be indispensable. Fittings, brace wires, tanks and other items must employ it, and it is highly desirable for parts under large, concentrated loads, such as landing gears and engine mounts.

An entirely different technique is required in working metal as compared to wood. Greater accuracy is both possible and necessary. Care must be taken to avoid surface scratches or other damage as they may start cracks. In the factories most small parts are punched out with accurate dies, but the field or service mechanic must make them by hand.

INTRODUCTION
(continued)

In making fittings or other small parts, great care should be taken that the material used is the same as that from which the original part was made. A piece of alloy steel with a tensile strength of 150,000 lbs. per sq. in. looks just like low carbon steel which is only one-third as strong. The comparative hardness of the two pieces can be distinguished to some extent by filing, and hardness is an indication of strength, but this is a very unreliable method of determining the properties of the material. About the only recourse the field mechanic has is to obtain a drawing from the factory, unless he is absolutely sure of the kind of steel and the heat treatment to which it has been subjected.

The properties of the metals used for structural purposes will be found in the following pages under "Properties of Metals." Before proceeding further, however, the student should become more familiar with the terms used in describing these properties.

Stress has been previously defined as a force tending to distort the material. As the word is commonly used, this definition is satisfactory. Technically, however, stress is the internal force which resists distortion. The amount of stress which a given material is capable of developing (or, in simpler language, the unit load in lbs. per square inch which the material will carry), can be determined only by test. Metals are commonly tested in a powerful hydraulic testing machine, capable of exerting a push or pull of many thousands of pounds. As the load is applied to a test specimen, the amount of the load is indicated on a scale. As previously explained, up to a certain point the distortion (or, the stretching in a tension test) is directly proportional to the load. As the pull increases, a point is reached (the yield point) where the stretching becomes much more rapid without proportionate increase in the load. Shortly thereafter the piece being tested breaks. The load at which it breaks shows the ultimate tensile strength, and, since the area of the section of the test specimen is known and likewise the load, it is a simple matter to convert the figure into lbs. per sq. in. For example, if the load carried were 20,000 lbs. and the specimen had a cross-sectional area of one-quarter of a square inch, its tensile strength would be 80,000 lbs. per sq. in. Fig. I shows test pieces of round stock (A) and flat stock (B). The ends are left large so that the jaws of the testing machine will not damage the portion being tested.

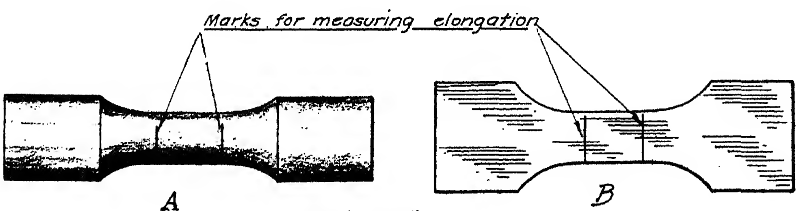
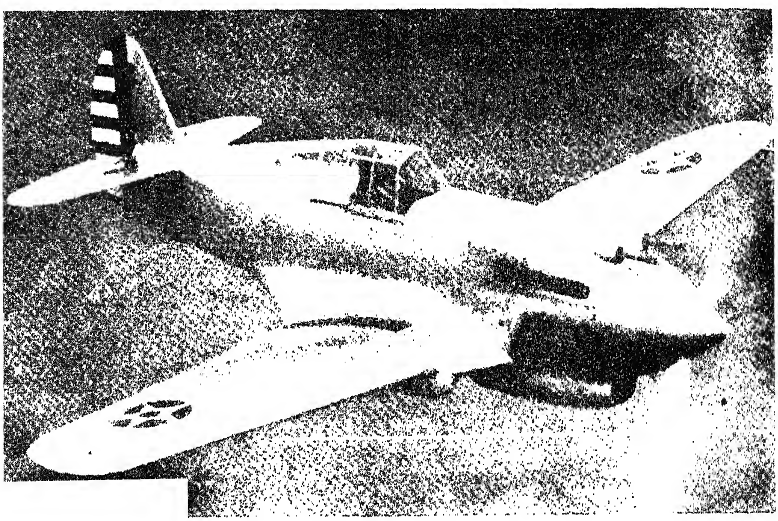


Fig. I

INTRODUCTION
(continued)

Before the metal breaks, it has usually stretched an appreciable amount. This amount is determined by making two marks on the specimen and accurately measuring the distance between them before the load is applied. Just before the piece breaks, the distance between the marks is measured again and the increase noted. The difference between the original dimensions and the measurement after the stretching has taken place is expressed in percentage of the original distance and is then referred to as the percent elongation. For example, if the original dimension were 2" and the dimension immediately before failure were 2.4" it would be said that the metal had a 20% elongation. This figure is an indication of the ductility of the material. The greater the elongation, the more ductile the metal. A small percentage of elongation indicates brittleness. As a general rule, the more ductile the material, the lower its tensile strength, although there are notable exceptions, such as cast iron, which has very little elongation or ductility and yet has not a particularly high tensile strength either. Another general rule is that the strength of metal in compression is approximately the same as its strength in tension. However, this is not so likely to be true in the case of castings of any material, as castings are usually stronger in compression than in tension.



CURTISS P40 ALL METAL PURSUIT

PROPERTIES OF METALS

Many volumes have been written on this subject so it is obvious that it cannot be covered completely here, nor is it necessary to go further than to mention those facts a mechanic should know concerning the metals used in aircraft. The table below lists the general characteristics of such metals. Steel and aluminum, being structural metals - that is, used for parts which carry loads, are discussed in greater detail under separate headings. The values given in the table are necessarily approximate, due to the wide variation of specifications of the various metals. The first three listed are classed as <u>ferrous</u> metals, the rest are <u>non-ferrous</u>.

Metal	Ultimate Tensile Strength Lbs/Sq.In	Weight Lbs/Cu.In.	Melting Point-°F	Magnetic
Cast Iron	15,000 - 40,000	.266	2200	Yes
Mild Steel	45,000 - 60,000	.283	2700	Yes
Alloy Steel	50,000 - 230,000	.283	2800	*Yes
Aluminum	13,000 - 25,000	.098	1220	No
Alum. Alloy	25,000 - 68,000	.101	1220	No
Cast Alum. Alloy	17,000 - 44,000	.101	1220	No
Copper	20,000 - 65,000	.322	1980	No
Brass	28,000 - 54,000	.312	1980	No
Phosphor Bronze	35,000 - 40,000	.321	1980	No
Manganese "	65,000 - 85,000	.295	1980	No
Tobin "	65,000 - 80,000	.295	1980	No

* This is true except for a few alloys, particularly some stainless steels, which are non-magnetic.

COPPER is used in aircraft chiefly in the form of tubing for fuel and oil lines, ignition wire and other electrical parts, and occasionally for rivets. It is very ductile when annealed, which is accomplished by heating red hot and quenching in cold water, though it will be fairly soft if simply allowed to cool in air. It is one of the elements and may be used in its pure state.

BRASS is a mixture or alloy of copper and zinc, the percentage of zinc varying from 15% to 40%. Usually, small amounts of tin, lead, or iron, or all three, are added. The percentage of these is seldom over 2% for any one of the three. It is used in aircraft very little except for pipe fittings. Small tanks are sometimes made of it.

BRONZE is an alloy of copper and tin, with sometimes zinc, lead, manganese or other elements added to modify its properties. Its uses are confined mainly to bearings, especially in engines, and occasionally cast fittings or other small parts.

MONEL is an alloy of nickel and copper, containing about 67% nickel, 28% copper and 5% iron, silicon, manganese, and carbon. It is highly resistant to corrosion, but no lighter than steel and not as strong. K-Monel is composed of 64% nickel, 30% copper, about 4% aluminum, with small quantities of iron, manganese and silicon. Its ultimate tensile strength may be as much as 175,000 lbs. per sq. in. It is subject to heat treatment but, probably due to its high percentage of copper, behaves somewhat like that metal. In other words,

PROPERTIES OF METALS
(continued)

if its temperature is raised to 1450° F. and it is than quenched in water or oil it becomes soft. The hardening process consists of heating it to about 1100° F. for six to eight hours and cooling it very slowly.

INCONEL is composed of 78% nickel, 13% chromium, 7% iron and small percentages of other minerals. It is not only highly resistant to corrosion but also retains most of its strength at high temperatures. For these reasons it is well adapted to the manufacture of exhaust collector rings and similar parts. When fully hard, its strength is about 125,000 lbs. per sq. in. It may be soldered with hard or soft solder and also welded by any of the conventional methods.

HAYNES STELLITE is an alloy of chromium, tungsten and cobalt. It is no harder than hardened high-carbon steel but does not lose its hardness even when raised to a bright red heat. It is very highly resistant to abrasion. It is used for coating valve faces and heads in engines and increases the life of the valve tremendously. It is also used on the bottom of tail skid shoes and will treble or quadruple their wear. It is applied to steel very much as bronze might be "welded" on, and by renewing it as it wears down, a tailskid shoe may be made to last almost indefinitely. This material is quite expensive, which is one of the reasons it is applied to a wearing surface only, rather than used for the entire piece.

Most metals are subject to the effect of heat and this property has been taken advantage of in the procedure known as HEAT TREATMENT, which includes, in general, all the various uses of heat to produce certain characteristics in the metal. Heat treating is another subject about which hundreds of books and articles have been written, and it is not necessary for the mechanic to have any very detailed knowledge concerning it. However, he should have some idea of what it means and know what is meant by the terms when they are used.

CURTISS P-42 PURSUIT

PROPERTIES OF METALS (continued)

Heating, when used in connection with heat treatment refers to the original application of heat, usually accomplished by putting the material in a furnace and bringing it up to a desired temperature. The heat may be supplied by coke, oil, electricity, and other means.

Quenching means lowering the temperature of the metal abruptly, usually by plunging it into oil or water, though the term is sometimes, on rare occasions, used in reference to cooling in air or by contact with other metal which is cold.

Reheating is the subsequent application of heat, usually to remove extreme hardness and brittleness. It is sometimes called tempering or drawing, and the temperature used usually determines the strength; the higher the temperature the lower the strength but the greater the ductility. The metal may or may not be quenched again, depending on the material and the properties desired.

Annealing is a softening process and consists of heating followed usually by a slow cooling, though some metals, such as copper, may be annealed by quenching after heating. The purpose of annealing is to prepare the metal for further work on it, or simply to eliminate brittleness. When metals are worked, i.e., rolled, drawn, forged, hammered, bent, or subjected to other strains, they become strain-hardened. If it is desired to continue working them, or if it is feared that they have become too brittle for use from such work or from welding, they may be annealed, or normalized.

Metal may be wrought, which means that the shape, such as sheets, bars or tubes, has been produced by rolling under pressure or drawing through dies; it may be cast, in which the metal is melted and poured into molds to produce the desired shape; or it may be forged, which consists of producing the form by compressing the metal between dies, either hot or cold, with a powerful hammer. For example, sheets of aluminum alloy are known as wrought aluminum alloy, the crankshaft of an engine is usually drop-forged, and the cylinder heads of radial engines are usually cast aluminum alloy.

STEEL

Steel, as the term is ordinarily used, consists of iron alloyed with carbon, with or without other elements to produce various properties, one of which is the capability of being hardened by heat treatment. There are hundreds of different combinations of alloys, and just as many types of steel, a few of which will be mentioned below.

The Society of Automotive Engineers (S.A.E.) has established certain specifications for steel among many other things. These steels have numbers which are partially descriptive of their composition. For further information refer to the S.A.E. Handbook at any library.

In the S.A.E. numbers, the first two digits indicate the

PROPERTIES OF METALS
(continued)

general class of the steel and the last two the desired amount of carbon in hundredths of one per cent. For example, 2330 indicates a 3-1/2% nickel steel with 0.30% carbon. The list below gives the numbers of the steels commonly used.

Carbon Steels	1---
Plain Carbon	10--
Screw Stock	11--
Nickel Steels	2---
.50% Nickel	20--
1.50% "	21--
3.50% "	23--
5.00% "	25--
Nickel-Chromium Steels	3---
1.25% Ni. .60% Chr.	31--
1.75% " 1.00% "	32--
3.50% " 1.50% "	33--
3.00% " .80 "	34--
Corrosion and Heat Resisting Steel (Stainless)	30---
Molybdenum Steels	4--
Alloyed with Chromium (Chrome-Moly)	41--
Alloyed with Chr. and Ni.	43--
" " Ni.	46--
Chromium Steels	5----
Chromium-Vanadium Steels	6---
Tungsten Steels	7---
Silico-Manganese Steels	9---

Those most common in aircraft are 1025, which is rapidly being discarded because its ultimate tensile strength is only about 55,000 lbs. per sq. in; 2330 for bolts, turnbuckles, etc., usually with a heat treatment producing about 125,000 lbs. per sq. in; and 4130, the well known "chrome-moly", used for tubing and sheet, at a strength of about 100,000 lbs. per sq. in. in its normal state, and for axles and other highly-stressed parts heat treated to 180,000 lbs. per sq. in. or more.

Nickel-Chromium steel, (3120-3145) is used for such parts as engine crankshafts and gears. Chromium steel (51235) is highly resistant to corrosion and hence is employed where this feature is desirable. Chrome-Vanadium steel (6120 to 6195) is capable of high tensile strength (up to 225,000 lbs. per sq. in.) after heat treatment. It is machined in its annealed state and heat-treated after fabrication. Tungsten steel (7260 to 71660) retains its properties well when heated and hence is used for exhaust valves, the magnets in magnetos, and other engine parts. Silico-Manganese steel (9250 to 9260) is used sometimes for springs.

STAINLESS STEEL

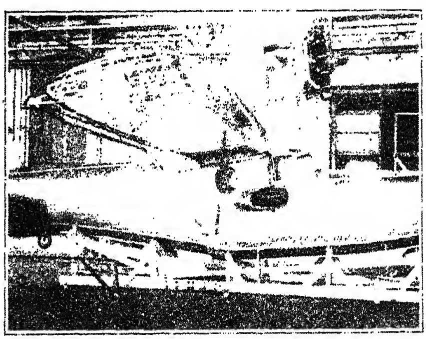
Stainless steel is, in many respects, a highly satisfactory material for aircraft construction. Due to its great strength, its remarkable resistance to rust, corrosion or general deterioration, and its adaptability to production methods, its use is becoming more and more widespread. For this reason, it is considered advisable to devote a chapter to its properties, its fabrication and repair.

For the use of the illustrations and some of the data, we wish to acknowledge the helpful cooperation of Fleetwings, Inc., Bristol, Pa., who are specialists in stainless steel construction. Other information has been obtained from the "Book of Stainless Steels", edited by E. E. Thum and published by the American Society for Steel Treating, Cleveland, Ohio. It is strongly recommended that the student mechanic obtain a copy of this book and familiarize himself with its contents.

DEVELOPMENT

Stainless steel was not primarily developed for aircraft use. And like many other important materials there were a number of different investigators concerned in its discovery, which was, to some extent, accidental. Mr. Harry Brearly, an English research engineer, was endeavoring to produce a steel suitable for the linings of large guns, such as those used on battle-ships. Such a steel must, of course, be able to withstand high temperatures and, at the same time, have great strength and toughness. In attempting to etch with acid some of his products for microscopic examination, he found one which refused to "etch" in the expected manner. This ultimately resulted in the discovery of stainless steel, for Brearly turned his attention to alloys which could be hardened sufficiently to be used for knife blades and found that these alloys when so heated were stainless.

It may seem hard to believe, but nevertheless, pure iron is soluble in water, of course, to a limited degree. This solubility is what causes rust. When iron is combined with carbon, thereby producing steel, it not only rusts like pure iron but the corrosion is more rapid, due to galvanic action between the iron itself and the carbides of iron (the combination of carbon and iron). To obtain a steel which will not rust or corrode, it is necessary to alloy it with some element which will render the iron insoluble and at the same time prevent galvanic action from causing corrosion.

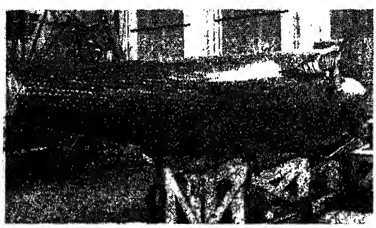


FLEETWINGS STAINLESS STEEL AMPHIBIAN

STAINLESS STEEL
(continued)

Brearley patented the combination of steel with 9% to 16% of chromium with less than .70% of carbon, realizing that over 16% of chromium prevented satisfactory heat treatment, in that the metal would not harden properly on quenching. Stainless steel cutlery was produced commercially in England in 1914.

The term "stainless steel" embraces a wide range of heat- and corrosion-resisting alloys of steel and chromium. Varying percentages of chromium, nickel, and other elements, produce varying properties, a discussion of which is far beyond the scope of this book. A little thought will readily unfold the almost unlimited field of uses. It is ideal for containers and vats for chemicals, for containers for food stuffs, milk, etc., for external structural work on buildings (the Empire State and the Chrysler Buildings in New York are notable examples), for automobile headlights, radiator shells, hub caps and other highly polished parts, for railroad coaches, and for many other purposes much too numerous to mention.



It is in its adaptability to aircraft, however, that we are particularly interested. Its first use in this field probably was for wing ribs, which when manufactured of this material show an extremely high ratio of strength to weight. That is to say, they withstand large loads without weighing much themselves. Stainless steel control cables are now on the market and the fine strands do not rust or corrode as do those made of other steel. Streamline tierods of stainless steel need no protective coating, and remain clean and bright indefinitely. Tanks for fuel and oil are light, strong, and corrosion resistant, when made of stainless steel. Hulls for flying boats and floats for seaplanes can be made of extremely thin sheets and still develop the requisite strength. Wing beams are light and strong. Stainless is practically non-magnetic, so the compass is not affected as it is in structures made of other steels. Exhaust manifolds and collector rings, due to the high temperatures and sudden cooling to which they are subjected, do not retain paint or other protective coatings well, and go to pieces rapidly except when made of stainless. Airplanes are now being built experimentally _entirely_ of stainless steel, wings, tail, and covering.

TYPES

As mentioned above, there are a great many varieties of stain-

STAINLESS STEEL
(continued)

less steel, due to differing percentages of the alloys. The strength of the material is affected not only by its composition but also by the heat treatment and the amount of cold working, such as rolling into thinner sheets, forming, spinning, etc. Table I gives the composition of several alloys.

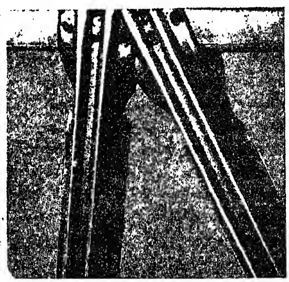
Designation	%Chromium	%Nickel	%Carbon	%Silicon	%Manganese	Ultimate Tensile Strength Lbs./Sq. In. Annealed	Coldworked
5% Cr.	4-6	-	.10-.20	.50	.50	66,000	115,000-
17% "	16-18	-	.10	.50	.50	75,000	100,000-190,000
18-8	17-19	8-10	.10	.50	.50	80,000	105,000-300,000
25-12	22-28	12-16	.15			100,000	110,000-270,000

Table I.

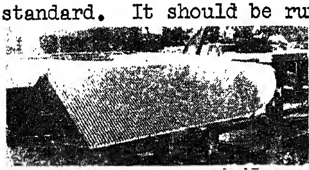
By far the best known and most widely used of the alloys listed above is the one referred to as "18-8", which contains 18% chromium and 8% nickel. It may be obtained in bars, tubes, and sheets, and is usually cold rolled to secure an ultimate tensile strength of about 180,000 lbs. per sq. in. In sheet form it is supplied in various degrees of polish, from a silvery satin finish to true mirror luster. The sheets may be had in any thickness from .005 to 1/2" and in width and length up to 250" x 60", but it is difficult to obtain in sizes larger than 120" x 36".

FABRICATION

The 18-8 can be fabricated in practically any way that other metals can, but not as easily, due to its stiffness. It may be stamped, punched, forged, cast, machined and spun. It may be soldered with either soft or silver solder, either to itself or other materials. It should not be brazed, but it may be welded by oxy-acetylene torch or electric arc. It may be spot welded, shot welded or flash welded, which will be further discussed below.


SHOT WELDED JOINT

In machining 18-8, the tools must be kept sharp and the speed reduced to, at most, half that required for ordinary screw stock. The material may be drilled without difficulty if the proper procedure is followed. If not, it may be found impossible to drill it. The drill should be made of high speed steel and ground slightly flatter than standard. It should be run at about half the speed used in drilling mild steel. The holes should be punch marked as lightly as possible, as punching deeply hardens the metal. Stainless should be backed up with some hard material which will cause the drill to cut all the way through without push- from the drill point ended for a backing


STAINLESS STEEL AILERON
WITH STRESSED SKIN

STAINLESS STEEL
(continued)

plate. Once the drilling is started, the cutting should be maintained continuously, as allowing the drill to make only a few revolutions without cutting will cause the metal to harden and at the same time burn the point of the drill. After the metal has been so hardened it is impossible to drill at that point without changing the angle of the cutting edge of the drill. In drilling deep holes, a cutting compound made of sulphur and lard oil in the proportions of one pound per gallon will be found of assistance.

POLISHING

It is sometimes desirable to buff parts which the mechanic might have occasion to make. Due to its toughness, 18-8 cannot be buffed by means which would put a high polish on ordinary metals. Several operations are required involving the use of manufactured abrasive grits of gradually increasing fineness applied to a buffing wheel with grease. No. 150 to 180 grit is used first, then Nos. 200, 240, and 280, in succession. The final polishing should be done on a different wheel using stainless buffing compound. This will give a mirror finish, and is not necessary except for external or ornamental parts. A wire brush or steel wool should never be used for any purpose on stainless steel.

SOLDERING

Due to the springiness of stainless, any joint that is to be soft-soldered should be riveted or spot welded and the solder used merely to make the joint tight. There is a special solder obtainable which needs no flux and which melts at a low temperature when applied, but resists fairly high temperatures after it is set. Ordinary solder may be used, however, if certain precautions are taken. The surface to be soldered should first be scratched with emery cloth and uncut phosphoric acid applied and left on for several minutes. It is necessary to use a large soldering iron because of the low thermal conductivity of the material, but the iron should be no hotter than necessary to melt the solder. It is sometimes necessary to keep the surrounding metal cool with copper chill plates or damp cloths, as buckling may result otherwise. Immediately after soldering the joints should be washed thoroughly with water. If the joint is not washed, the acid will continue to etch the material. Likewise, when silver soldering, the flux should be removed as soon as the soldering has been completed. If a ready made flux is purchased, instructions for removing should be on the package. A mixture of potassium fluoride and borax makes a satisfactory flux and may be cleaned off with a small, high pressure steam jet.

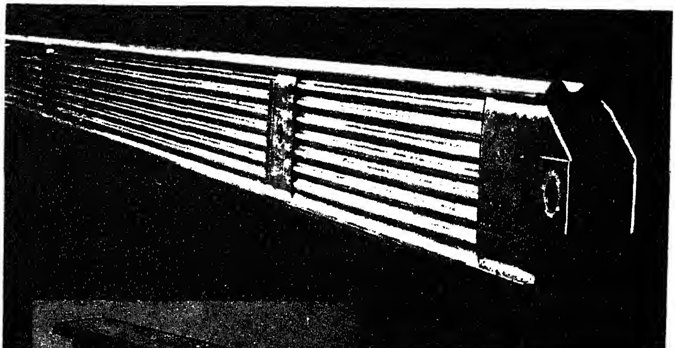
WELDING

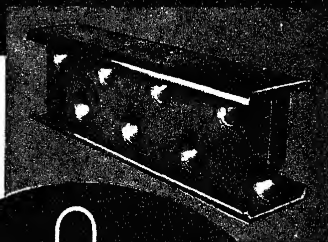
The most satisfactory means of fastening stainless steel is welding. As mentioned above, there are several types of welding, namely, torch, arc, and resistance, the last being subdivided into spot welding, shot welding and flash welding. General instructions on welding will be found in the chapter on that subject. The comments following apply specifically to stainless.

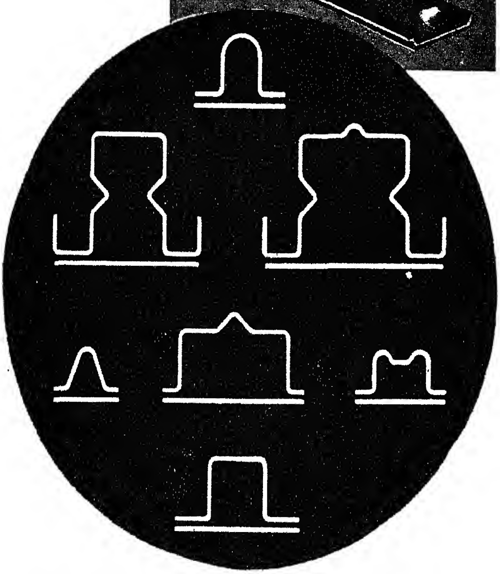
In using the oxy-acetylene torch, a neutral flame just large

STAINLESS STEEL
(continued)

TYPES OF STAINLESS STEEL BEAMS







TYPICAL SECTIONS OF STRINGERS USED WITH STRESSED SKIN

enough to insure proper fusion should be used. Too much heat results in a porous weld. If the flame contains too much acetylene, carbon will be absorbed by the hot metal, which lessens resistance to corrosion and also makes the metal more brittle. If there is an excess of oxygen, a quantity of infusible oxide will be formed.

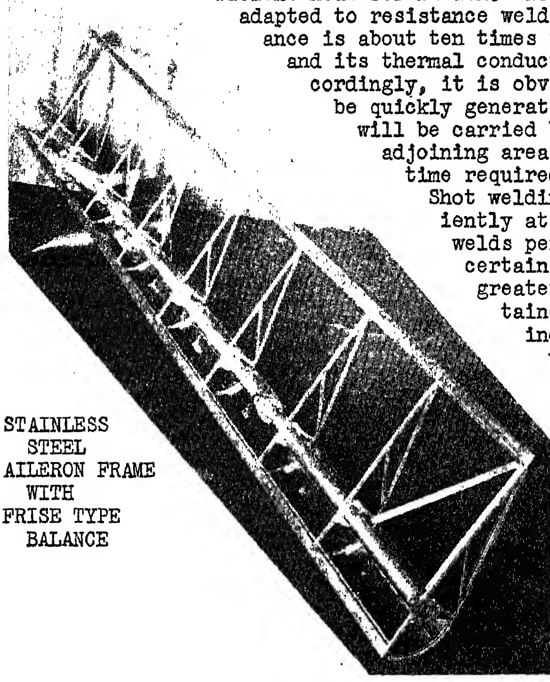
For sheet 16 gauge or lighter, flange welds, similar to those used in welding aluminum are usually employed, the edges being bent up to a height of about 1/16" and then melted down. Flux must be applied on both top and bottom of the seam. Butt welds may be made with welding rods of the same material, a backing strip of some material of high thermal conductivity being placed under the seam. Care must be taken not to melt through and cause the backing strip to alloy with the weld. In sheets up to 1/8" thick, it is not necessary to bevel the abutting edges of the sheets, but the flux must be applied on both top and bottom surfaces. If the seam is placed at a slight angle, the flux will flow ahead of the weld as it is melted, mater-

STAINLESS STEEL
(continued)

ially aiding in making a good looking job. For thickness up to 1/8" the forward method (right to left for a right-handed person) should be used, while for thicker stock the back-hand method (left to right) will be found more satisfactory. Welding should usually be done on one side only and the welding rod should not be puddled.

The procedure in arc welding "18-8" stainless is approximately the same as that employed with other steel. The shielded arc process is used, that is, the electrodes are covered with a coating which shields the arc and the molten metal from atmospheric contamination. In general, less voltage and amperage is necessary with 18-8 than with ordinary steel. It is also desirable to use somewhat shorter electrodes, 11" and 9" being used instead of the customary 14". It is extremely necessary to have the joint clean to begin with and to keep it clean.

Resistance welding is that type of electric welding in which the electrical resistance of the material being joined causes sufficient heat for fusion. 18-8 is particularly adapted to resistance welding since its resistance is about ten times that of mild steel, and its thermal conductivity 40% less. Accordingly, it is obvious that heat will be quickly generated at the joint but will be carried back slowly into the adjoining area. Furthermore, the time required for welding is less. Shot welding can be done conveniently at the rate of 100 welds per minute, and under certain conditions much greater speed can be obtained. Tests on welds indicate that when made up under proper conditions they develop the full strength of the material, and when specimens are broken in the testing machine, the break occurs some distance from the weld.



STAINLESS STEEL AILERON FRAME WITH FRISE TYPE BALANCE

Flash welding is a form of resistance welding in which the two pieces which are to be joined are fitted so that they form a good contact at all parts of the joint, after which the pieces are clamped into two dies. The dies are then connected to a suitable source of electric current and moved toward each other at a predetermined speed. As the ends of the parts to

STAINLESS STEEL
(continued)

be welded approach each other, an electric arc is generated between the two. Flashing then begins and by bringing the ends together a definite amount, the proper volume of metal is displaced. The circuit is then opened and sufficient pressure applied to upset the ends of the two pieces, thus uniting them. It requires less than half a second to make a weld of this type in half-inch round bar stock. The dies are usually made of copper and must fit the work accurately. When the weld is complete, the distance between the inside faces of the dies should not be more than 1/16".

Probably the most widely used and satisfactory method of joining sheet stock is by spot welding. Spot welding consists of gripping two or more sheets of metal between two electrodes and passing a current through. An outgrowth of spot welding is the process known as "shot" welding, in which automatic machines are used, and all conditions - time, pressure, and current - accurately controlled. The equipment is expensive and a certain amount of experimental work necessary on each new problem. Once the proper procedure is worked out, however, production is rapid and the quality of weld excellent. Small spots can be twisted through 90° before breakage occurs. With roller electrodes, 960 shot welds per minute can be made. When this is compared with rivetting the production possibilities become apparent. Where it is necessary to have the seams water-tight or gas-tight, as in boat hulls, tanks, etc., the spots overlap so that a continuous unbroken joint results.

When stiffeners are used on thin metal skins, it is possible to carry the stresses much more satisfactorily than could be done with rivets, because of the closeness with which the spots can be placed. Furthermore, the spots weigh nothing and can be used on a very narrow flange, whereas, in a riveted joint, the weight of the heads and the wide flange add appreciably to the weight of the structure. It has been demonstrated many times by tests that shot welds are stronger than rivets of the same size.

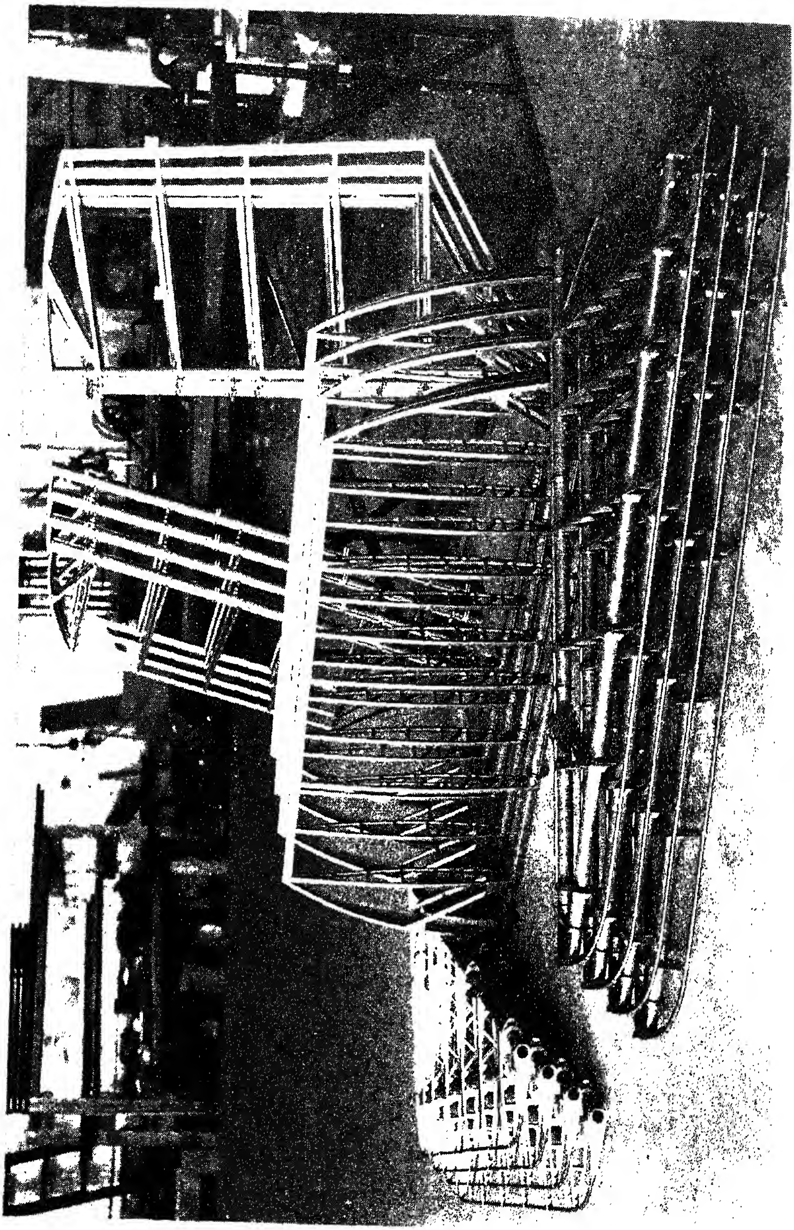

PUNCH WELDING

Shot welding may be done where riveting is difficult or impossible because rivets have to be bucked. By using a "poke" welder, which is a portable electrode so designed that the current is not turned on until proper pressure is applied to the joint, spots can be welded simply by placing one electrode in contact on the inside of the structure and applying the poke welder on the outside at the point where the weld is desired. This process is highly advantageous in boat hulls, since there are no holes drilled as there would have to be for rivets, and, hence, no possibility of leaks.

FUTURE

Stainless steel may be used to much greater advantage in

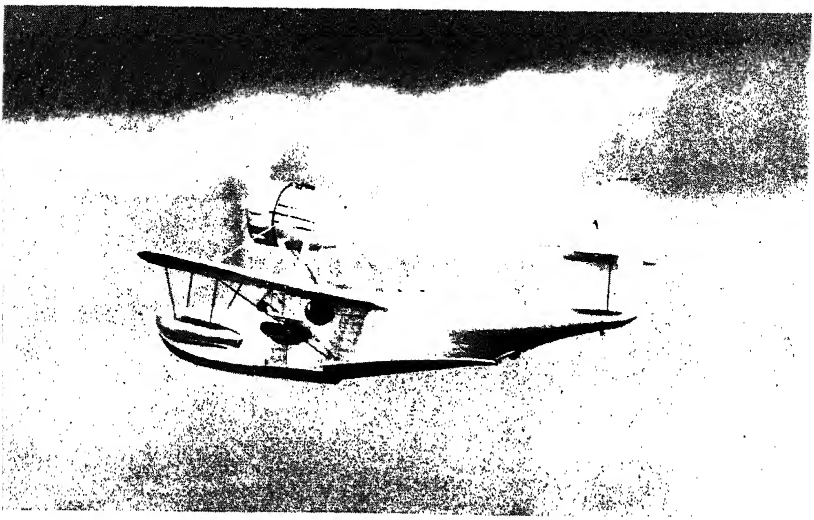
STAINLESS STEEL
(continued)



ALL-STAINLESS STEEL TAIL SURFACES

STAINLESS STEEL
(continued)

large ships than small ones, due to the fact that if parts were made of thin enough material to use the full strength, they would be too easily bent in service. In the large ships, where loads are greater, thicker stock is necessary and the full strength of the material may be developed. Since the trend today is toward larger and larger planes, it is safe to predict that stainless steel construction has an almost unlimited field of future possibilities.



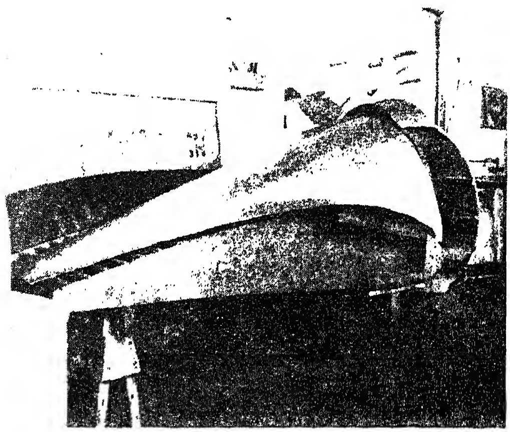
FLEETWINGS "SEABIRD"
A Five-Place Stainless Steel Amphibian Boat

ALUMINUM

Aluminum is the fifth most commonly used metal today, but this statement applies to everything built of metal from the frames of skyscrapers to kitchen utensils. In aircraft use it is unquestionably entitled to second place if not first. By the term aluminum, as used here, is meant all of its alloys, for most of them contain approximately 95% of pure aluminum. The word duralumin is used widely in the trade in referring to certain alloys of aluminum manufactured by the Aluminum Company of America, the largest manufacturers of aluminum in this country and probably in the world. The data following is taken from their literature, to which the student is referred for more detailed information.

GENERAL

As to the characteristics of aluminum which are responsible for its widespread use, the aviation mechanic is chiefly interested in three: its light weight (approximately 1/3 that of steel), its high resistance to corrosion when properly treated, and its ease of fabrication. "Commercially pure" aluminum may contain up to 1% of other elements, chiefly iron and silicon. It is not particularly strong but in its soft condition is very easily formed or "bumped". The metals with which aluminum is commonly alloyed, in varying quantities to produce various characteristics, are copper, silicon, manganese, magnesium, chromium, iron, zinc, and nickel. These metals may be added singly or in combination to produce high strength, high resistance to corrosion, etc.



"BUMPED" ALUMINUM FAIRING FOR ENGINE NACELLE

USES

Commercially pure aluminum is used in airplanes principally for non-structural parts, such as cowling, wings, root fairing, wheel "pants", and any other part which has to be "bumped" to shape, and for welded gas and oil tanks.

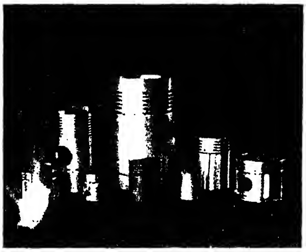
Aluminum alloys are used for every type of structural part, ribs, beams, wing skins, monocoque fuselages, seaplane floats, flying boat hulls - in fact, it is hard to name any part of an airplane for which it is not used by some designer. In the engine, the cylinder heads, pistons, crankcases, rockerbox covers and other parts are made of aluminum alloy castings, and the blades of most

ALUMINUM
(continued)

metal propellers are made of aluminum alloy forgings. Aluminum foil (which is extremely thin sheet) is used for protecting wood propeller blades; in place of dope proof paint, on parts which are to be covered with fabric; and for protecting steel parts, such as fuselage members, from rust.

FORMS

Wrought alloys are those which are designed to be used approximately in the form in which they are received. In this class are foil, sheet, bars, rods, wire, tubing, rivets, nails, bolts, nuts, screws, structural shapes, moldings, and various extruded sections.



ALUMINUM ALLOY PISTONS

Casting alloys are those which are to be melted and cast for such parts as cylinder heads and engine parts, and special fittings where high tensile strength is not essential. Aluminum may be cast in sand, in metal molds, or in die-casting machines under pressure.

"Alclad" is the registered trade mark used by the Aluminum Company in referring to a special form of sheet in which certain alloys are coated on both sides with chemically pure and, hence, highly corrosion-resistant aluminum. It is used for such parts as seaplane floats, flying boat hulls, and in any other place where extreme resistance to corrosion is desirable. The pure aluminum coating not only protects the portion of the sheet which it covers, but also, by electrolytic action tends to prevent corrosion on the edges of the sheet and even affords protection to uncoated rivets used in the fabrication. While this action sometimes, after long exposure, causes an appearance of corrosion on the outside, by proper cleaning methods the mottled effect may be removed without damaging the face or destroying the protective coating.

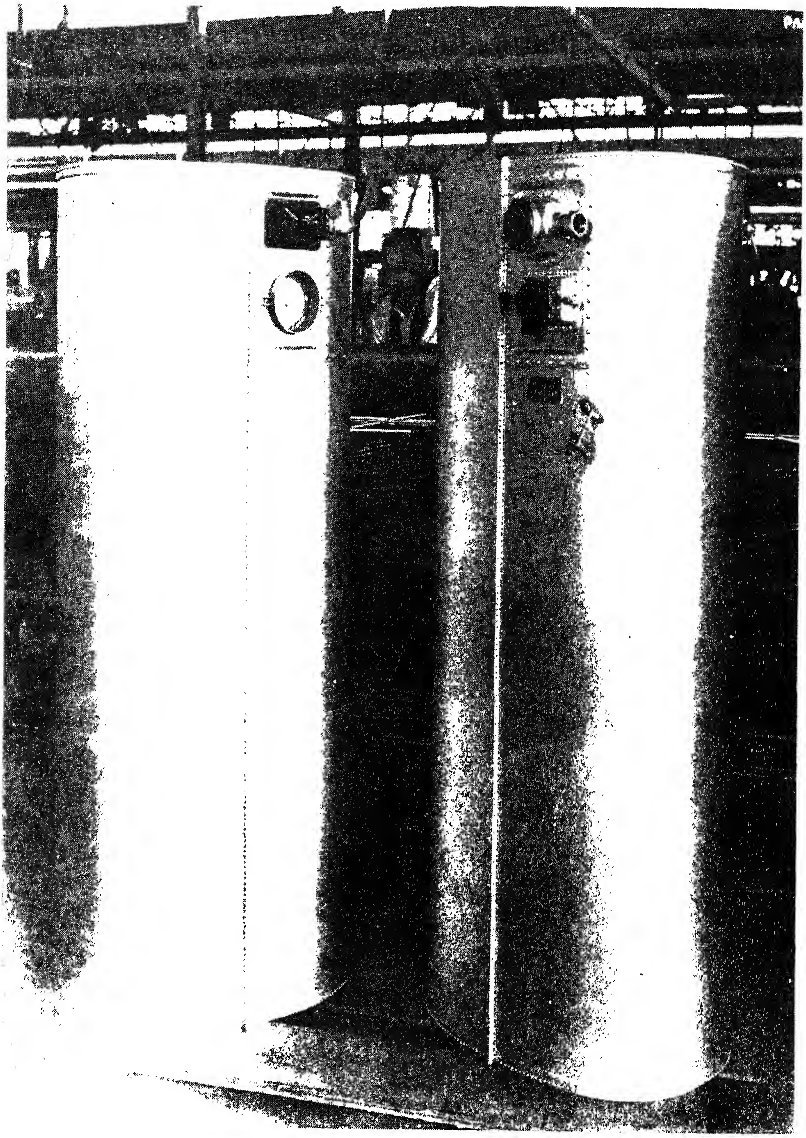
ALUMINUM ALLOY CRANKCASE

FABRICATION

Commercially pure aluminum in the soft or annealed condition is extremely ductile and may be punched, drawn, spun, or hammered into almost any conceivable shape. It welds easily and without much loss of its properties, and for this reason and its light weight is one of the favorite metals for tanks. Various types of solder have been developed for use with aluminum, but so far there are none on the market which are

CAST CYLINDER HEAD

ALUMINUM
(continued)



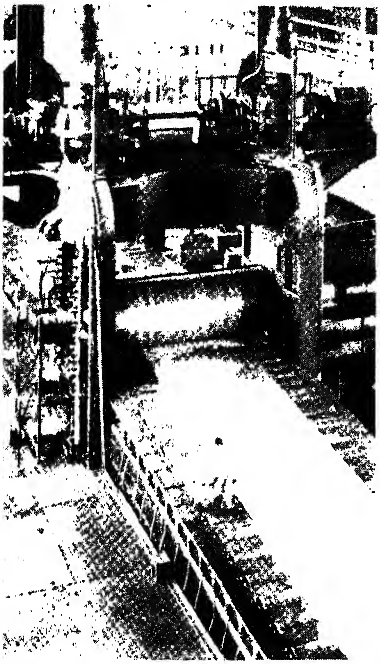
Courtesy Sikorsky Aircraft.

RIVETTED ALUMINUM ALLOY 100 GAL. GAS TANKS - SIKORSKY S-43
NOTE DUMP VALVE AND FILLER CAP

ALUMINUM
(continued)

entirely satisfactory.

The various alloys may be welded by any of the conventional means, namely torch, electric arc, or electrical resistance. The latter includes spot or "shot" welding, seam welding, and butt or flash welding. The general procedure will be found in the section devoted to "WELDING". In the majority of aircraft, however, joints are still usually made by means of riveting - also discussed in detail later.



ROLLING ALUMINUM PLATE

The heat-treatable alloys may be formed similarly to those not subject to heat-treatment, but with somewhat less facility. Severe forming, sharp bends, etc., should be made only when they are in the annealed condition. The radii for bends in aluminum alloy in both the annealed and the heat-treated conditions will be found in the section devoted to "BENDING FITTINGS".

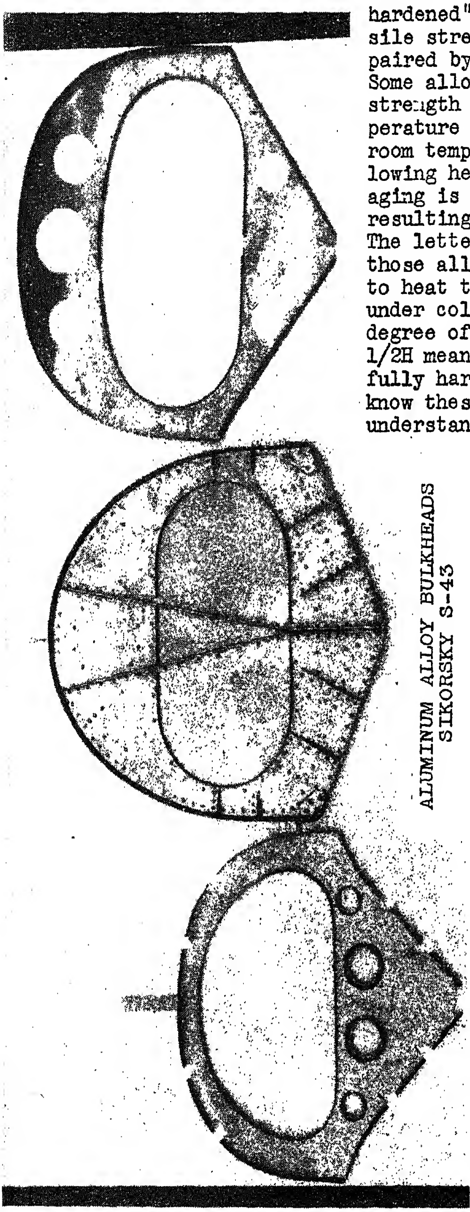
DESIGNATION OF ALLOYS AND TEMPERS

The Aluminum Company uses numbers followed by a letter to distinguish its various alloys. There are a number of these but only a few find general use in aircraft. Other letters follow the material designation to describe the condition, i.e. whether annealed, heat treated, half-hard, etc. Since the mechanic has little occasion to make castings, the various casting alloys are not discussed further.

The most popular form of approximately pure aluminum is known as 2-S. This is supplied in sheet, plate, wire, rod, bar, extruded shapes, tubing, and rivets. 3S, which contains 1.25% manganese, is supplied in the same shapes, 17S, which is the alloy usually referred to when the words "duralumin" or "dural" are used, is supplied in these forms, and also rolled shapes and forgings. 51S comes in the same forms as 2S, 24S, and Alclad 17S and 24S are supplied only in sheets.

The letter T following a designation number means that the material has been heat-treated. The letter O indicates the dead-soft or annealed condition. RT means that it has been cold-worked (rolled or drawn) after heat treatment and, hence, has been "strain-

ALUMINUM
(continued)



ALUMINUM ALLOY BULKHEADS
SIKORSKY S-43

hardened" to a slightly higher tensile strength. The ductility is impaired by this process, however. Some alloys attain their full strength only by "aging" at a temperature considerably higher than room temperature immediately following heat treatment. If this aging is not done, the lower strength resulting is called the W temper. The letter H is used in referring to those alloys which do not respond to heat treatment but which harden under cold-working, and denotes the degree of hardness. For example, 1/2H means half-hard and H means fully hard. It is necessary to know these distinctions in order to understand subsequent information.

HEAT TREATMENT

The heat treatment of such aluminum alloys as respond to it differs considerably from the heat treatment of steel, discussed in the preceding pages. The temperature is much lower and there is usually no drawing or reheating procedure. Also, aluminum alloys are usually heated in a bath of melted sodium nitrate, so as to secure perfectly uniform distribution of temperature, though it may be heated in air, if it is so circulated as to secure such uniformity. The bath itself has no connection with the "solution heat treatment", as this expression applies to the action which takes place in the metal, regardless of whether the heat is supplied in a bath or in air.

ALUMINUM
(continued)

The solution heat treatment consists of heating the metal to a high temperature to put as much as possible of the alloying material into a solid solution and then quenching in cold water to retain this condition. In effect, the alloying material has been dissolved in the aluminum. After quenching, the alloy does not immediately possess the strength it ultimately acquires, in most cases requiring about four days, though it reaches about 90% of the maximum the first day. This is the aging process, and occurs spontaneously at room temperatures in some alloys such as 17S. Others, such as 51S require an artificial aging at about 300° F for 18 hours. This is known as the "precipitation heat treatment" and if omitted leaves the metal in the condition of temper designated by W.

ALUMINUM ALLOY RUDDER FROM SIKORSKY S-43
NOTE CUT-OUT FOR TRIMMING-TAB

The heat treatment temperature for 17S is 930° - 950° F, held 5 to 30 minutes, depending upon the thickness of the material. After immediately quenching in cold water and aging for four days, the designation of the metal is 17ST. The temperature for 24S is 910°-930°F, and the rest of the procedure the same except that the minimum time is 30 minutes. Its designation is then 24ST. For 51S, the temperature is 960°-980°, quench in cold water. If used without further treatment, it is known as 51SW, if aged for 18 hours at 315°-325° it becomes 51ST. No time should be lost in quenching any of the alloys after removing from the bath or furnace, as a delay of fifteen seconds may seriously impair both

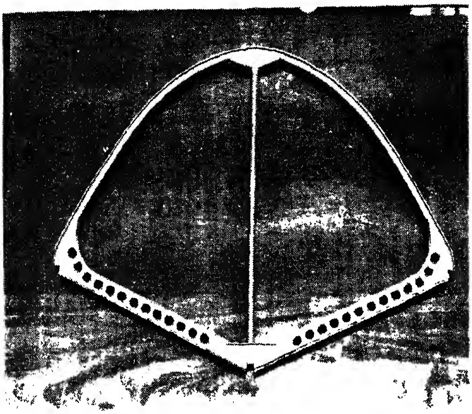
ALUMINUM
(continued)

the strength and resistance to corrosion.

ANNEALING

When aluminum or its alloys are worked (bumped, formed, rolled, or drawn) they become strain-hardened. This hardening may be removed by annealing.

Annealing is accomplished by heating the metal to 640°-670°F and slow cooling to 450°F after which the rate of cooling is unimportant. This removes the effects of cold working, and most of the effects of any previous heat treatment.



FLYING BOAT FRAME

To bring the material to the dead-soft, fully annealed or "O" condition, the following procedure must be used for heat treated alloys. Heat at 750°-800°F for two hours and then cool in the furnace to a temperature of 500°. The cooling rate should not be faster than 50° per hour down to this point. The cooling rate from 500° to room temperature is unimportant.

OMPOSITION

The table below gives the percentage of alloying elements added to the pure aluminum to produce the various alloys.

Alloy	Copper	Silicon	Manganese	Magnesium
3S			1.25	
17S	4.00		0.50	0.50
24S	4.20		0.50	1.50
51S		1.00		0.60

It is often difficult to distinguish pure aluminum from the lloys by appearance alone, and though in the heat treated condiion the alloy is much stiffer, the difference in stiffness beween annealed alloy and hard aluminum is not conspicuous. A simle test is to pour a solution of lye on the metal. The alloy ill turn black due to the chemical reaction between the lye and he copper.

ALUMINUM
(continued)

STRENGTH

The table below shows the strength and other physical properties of the alloys discussed.

Alloy and Temper	Tensile Strength Lbs./Sq. In.	Elongation % in 2 In.	Shearing Strength Lbs./Sq. In.
2S-0	13,000	35	9,500
2S-1/2H	17,000	9	11,000
2S-H	24,000	5	13,000
3S-0	16,000	30	11,000
3S-1/2H	21,000	8	14,000
3S-H	29,000	4	16,000
17S-0	26,000	20	18,000
17S-T	60,000	20	36,000
17S-RT	65,000	13	38,000
Alclad 17S-T	56,000	18	32,000
Alclad 17S-RT	57,000	11	32,000
24S-0	26,000	20	18,000
24S-T	68,000	19	41,000
24S-RT	70,000	13	42,000
Alclad 24S-T	62,000	18	40,000
Alclad 24S-RT	66,000	11	41,000

GENERAL COMMENTS ON MAINTENANCE OF ALUMINUM ALLOY STRUCTURES

(Specific instructions for repair of wings, fuselages, floats, hulls and other structures are given in the respective sections devoted to those subjects. The notes below, however, should be borne in mind whenever work is being done on parts made of aluminum alloy.)

Replacement parts should invariably be made of the same alloy, with the same heat treatment, as the original. Too much emphasis cannot be laid on this point. From the list above, it will be noted that there are a number of alloys, the properties of each of which not only differ from those of other alloys, but also vary with the heat treatment. There is no way in which the mechanic can definitely determine which heat treatment is used without reference to the drawings of the part. Obviously, if a replacement is made from a weaker alloy, or from one improperly heat-treated, failure of the structure is likely to occur.

Under no circumstances should a torch be used in straightening heat-treated members, as not only is the strength almost sure to be lowered, but the resistance to corrosion is decreased also.

When removing rivets for replacement of damaged pieces, the heads should be drilled off and the rivet punched out with a flat pointed drift. Or the heads may be drilled with a bit of smaller diameter than the rivet and a specially ground cold chisel with

ALUMINUM
(continued)

rounded corners, used to complete the removal of the head. The use of a chisel alone, without drilling first, is likely to enlarge the rivet hole. The chisel, when used in conjunction with the drill, should be bevelled only on one side, and when so ground is referred to in the trade as a "rivet-buster" chisel. Fig. I shows a section through a rivet, properly drilled, with the chisel in place for removal of the rivet head.

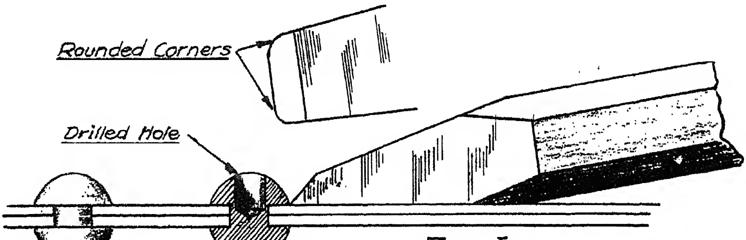


FIG. I

Aluminum alloy structures must be kept clean, particularly in the vicinity of salt water, as dirt tends to permit corrosion to start. However, Alclad should not be cleaned with abrasive cleaning materials, and none of the alloys should be subjected to the chemical action of certain powerful cleaning fluids. If a polished surface is desired, "Bon Ami" and fresh water should produce satisfactory results on either Alclad or the uncoated alloys. The Aluminum Company of America is of the opinion that the abrasive action of this cleaner is so mild as to be harmless. Another preparation, known as "Alumi - Nu" and composed of wax with a small amount of mild abrasive, is also considered safe.

If only cleanliness, without polish, is desired, a neutral soap or a sodium phosphate cleaner may be used. One product, known as "Turco 400", when mixed with six parts of water is said to be capable of removing even stains caused by exhaust fumes without damage to the metal.

Below is an important list of "dont's" pertaining to aluminum alloy:

Don't mark aluminum alloy with a scriber, as it will crack on the scribed line; use a soft lead pencil for layout.

Don't bend aluminum alloy over a radius less than that specified. See page 117.

Don't scratch or scrape aluminum alloy, whether painted or unpainted. It may start corrosion.

Don't clamp aluminum alloy in a vise without aluminum or wood face-pieces, which have been wiped clean.

Don't bend aluminum alloy along the grain.

Don't use an aluminum alloy without being sure that it is the alloy specified. Note difference in strengths in preceding table.

DESIGN OF FITTINGS

While the mechanic is not expected to design fittings - or, for that matter, any other part of the airplane - occasions sometimes arise where emergency repairs are necessary and he should have at least enough knowledge of the subject to do a safe job.

It is rather difficult to define a "fitting." A broad definition might be that it is a part, made of metal, used to attach members, or other parts, to each other. Thus we have wing hinge fittings, by means of which the wing spars are fastened to the fuselage; lift and landing wire fittings, to attach these wires to wing or fuselage; strut fittings, to fasten the ends of struts; and many other types. Often one fitting may serve a combination of purposes, such as providing, by means of different lugs, an attachment for drag wires, drag strut, lift wires, and interplane strut all at once. Hence, a fitting may be only a simple flat strap, or it may be a complicated structure made of many small pieces welded, riveted or bolted together.

In making new fittings to replace those which have been damaged, great care should be taken to use material which is at least as strong as the original piece. Naturally if the part being replaced is in such condition that it may be measured, the new one should duplicate it exactly. If, however, such measurements cannot be made, the notes below should serve as a guide.

A fitting is usually a part of the primary structure - that is, the structure which carries the stresses. Hence, the fitting may be subjected to any of the five types of stress, or to a combination of two or more stresses, just as any other structural member. Attachments are usually made by means of lugs, to which the members are secured by aircraft bolts.

<u>Caution</u>: Never use anything <u>but</u> aircraft bolts in the primary structure. Ordinary machine bolts will carry less than half as much load as aircraft bolts and their use invites disaster.

The stresses which usually determine the design of a fitting are bearing (which is a form of compression), tension, shear, and bending. A brace-wire lug is often subjected to the first three, and frequently to the fourth also, at the same time.

Consider the lug in Fig. I, which is subjected to a force acting in the direction of the arrow. The load which the lug will carry in tension, may be easily determined if the U.T.S. (ultimate tensile strength) of the material is known. The formula for this is simply U.T.S. x W x T, where W is the width of the shank and T the thickness of the material. As an example, assume that U.T.S. = 90,000 lbs. per sq. in.; W = 3/8, T = 1/8. Using decimal equivalents for the fractions we have 90,000 x .375 x .125 = 4,220 lbs. Furthermore, if tension alone were all that need be considered, the dimension "b" could be

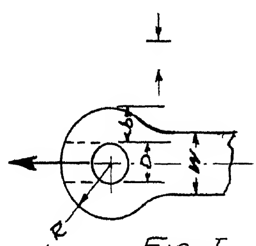


FIG. I

DESIGN OF FITTINGS
(continued)

$\frac{1}{2}$ W so that the radius R would then be $\frac{1}{2}$W plus $\frac{1}{2}$D.

However, there is more to the story than this. The pin or bolt, which carries the load into the fitting, tends to make the material shear along the dotted lines. Hence, this portion of the lug is subjected to both tension and shear, which requires that R be greater than $\frac{1}{2}$W + $\frac{1}{2}$D. It is extremely difficult to calculate just what R should be. The table below gives the minimum dimensions for lugs, based on actual tests of many specimens. It will be noted that the strengths of the lugs conform to the rated strengths of the various tie rods, which will be discussed in a later chapter. The dimensions in the table are those specified by the Army Air Corps and the Navy.

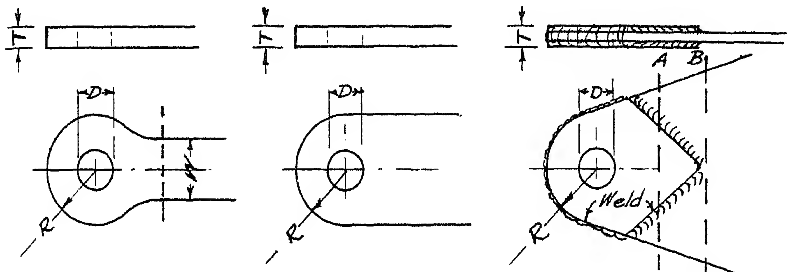


Fig. II

MINIMUM DIMENSIONS FOR TIE ROD LUGS

T	D	Rated Strength of lug in lbs.	55,000 U.T.S. R	55,000 U.T.S. W	Rated Strength of lug	90,000 U.T.S. R	90,000 U.T.S. W	125,000 U.T.S. R	125,000 U.T.S. W
3/32	13/64	1,100	17/64	1/4	1,200	9/32	5/16	7/32	1/4
1/8	13/64	2,100	11/32	3/8	2,400	3/8	3/8	9/32	3/8
3/16	17/64	3,400	13/32	7/16	4,200	13/32	9/16	3/8	1/2
3/16	25/64	6,100	45/64	3/4	6,900	23/32	13/16	9/16	5/8
1/4	25/64	8,000	45/64	3/4	10,000	23/32	7/8	9/16	5/8
5/16	29/64	12,500	13/16	7/8	13,700	13/16	1-	5/8	7/8
3/8	33/64	17,500	15/16	7/8	18,500	15/16	1-1/8	3/4	1-

When a lug is subjected to a straight pull, the shape shown in Fig. II (a) is satisfactory. If, however, bending is also present, as in the case of an installation such as that shown in Fig. III, or if its lug is subjected to vibration, the shape shown in (b) is better. Sometimes it is desirable to make the rest of the fitting of thin material

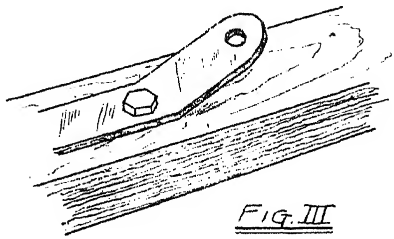


Fig. III

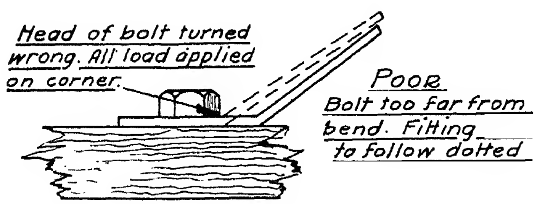
DESIGN OF FITTINGS
(continued)

to save weight. In such cases, washers may be welded on as shown in II(c). If this practice is followed, the strength of the lug must be calculated at several sections, such as A - A and B - B to be sure that it does not fall below the minimum allowable.

If the tensile strength of a lug, made to the dimensions given in the table on the preceding page, is calculated, it will be found that a higher figure is obtained than that in the table. The table gives the rated strength of the lug. Both the military and civil air regulations require that fittings have an excess strength of at least 80%. Thus the lug for a 2,100 lb. tie rod must show a calculated strength of 1.8 times 2,100, or 3780 lbs.; and if the student is sufficiently interested to check against the table he will discover that the calculated strength of all the lugs are approximately 80% greater than the rated strengths. Slight variations from the exact figure are due to the fact that widths and thickness are specified only to the nearest thirty-second of an inch.

Due allowance must be made, of course, for any bolt holes in fittings, and likewise for lightening holes. The latter, as the name implies, are large holes made for the purpose of reducing weight. They are used in fittings which are bolted to members of wood or other soft material which requires that the attaching bolts be widely separated to avoid concentration of the load.

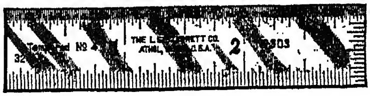
When fittings are made of a number of pieces welded together, the design should be such, if possible, that the welds are not in tension. Also, as far as practicable, welds should not run straight across lugs. Bolts, when used as in Fig. III, should be as close to the bend as possible, with the flat of the head parallel to the bend. Fig. IV shows poor practice, since the fitting tends to bend at the bolt, and the bolt head is not turned to the proper position.



THE STEEL RULE

The better grade of steel rules are made of spring-tempered steel and are graduated in any desired manner. The standard graduations are 1", 1/2", 1/4", 1/8", 1/16", 1/32" and 1/64". For special purposes they are also supplied graduated into 1/10" and 1/12". A good rule or scale is not only accurately graduated, but the edges are carefully machined so that the rule may be used as a straight edge.

FIG. I



In using a steel rule or scale for laying out a metal fitting, the rule may be placed directly on the material and the measurements taken from the rule. If this method is used it is more accurate to take the measurement from the inside graduations on the rule. This is done as shown in Fig. II by placing the rule at right angles to the material and picking off the correct measurement with the scriber. Another accurate method often used is to set the dividers to the correct measurement on the rule and then transfer to the material.

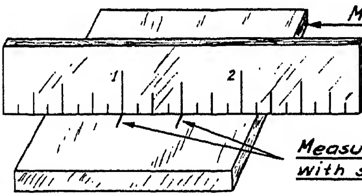
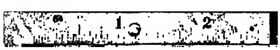


FIG. II

In addition to the rule being used for measurements it is constantly used as a straight edge in scribing lines. It is also used to check the trueness of an edge. By placing the rule and the work edge to edge, then holding up to the light, it can be seen at a glance if the working edge is straight. This is especially useful in making fittings.

For convenience in measuring small rods, tubes, sheet stock, etc., a caliper rule is used. In addition to the standard graduations on the face, the caliper rule has a graduated sliding arm with a contact on the end. When an object is clamped between the end of the rule and the contact end, the reading is taken directly from the sliding arm, Fig. III.

FIG. III



THE METAL SCRIBER

The scriber is a tool used to lay out metal fittings, to trace templates, etc. In general, it can be referred to as a pencil for drawing on metal. A clearly defined layout is of utmost importance in turning out an accurate job in metal work. This means that all lines must be sharp and clear cut. All lines must be fine and not too deep. This cannot be done with a blunt or soft tool.

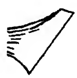
The scriber consists of a hard steel wire, with one end sharpened to a fine point. Usually the point is tempered to preserve its sharpness. The other end is also sharpened and then bent to form a right angle with the wire. This is useful in reaching through holes, etc. The convenience of the scriber is greatly improved if a sliding knurled handle is slipped over the wire to provide a better grip.

For the extremely accurate work of pattern making, a knife edge scriber is often used. The knife edge scriber can be used to lay out patterns on wood, as a much sharper line results than when using a pencil.

Scribers can be made by sharpening one end of a hard wire on the emery wheel. However, if much work is to be done, a scriber of the general type shown below, which may be purchased at any hardware store, will prove to be more useful.

Scriber

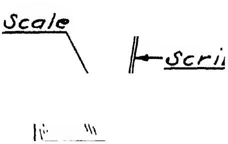
Fig. I



Knife

In use, the scriber should be held in the fingers the same as a pencil. The scriber is inclined so that the point will be close to the straight edge or the template, Fig. II. It should also be inclined slightly in the direction of the stroke to insure a steady line, Fig. III.

Note: Make one firm line. If this is done it will not be necessary to trace over a scribed line.



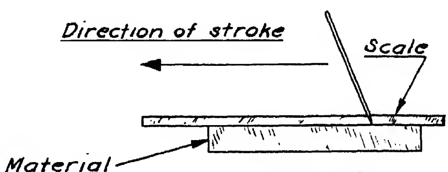
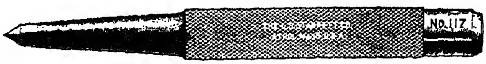


Fig. III

THE PRICK PUNCH

The prick punch should not be confused with the center punch, as it is never correctly used to make the center mark for drilling. It is used only in layout work for marking locations and making the center mark for scribed circles. The prick punch is a lighter tool than the center punch and the point has a greater taper, Fig. I.



Prick Punch Fig. I

The prick punch is held between the thumb and the first and second fingers of the left hand so that the tip of the second finger is resting lightly but firmly, close to the point of the punch and also on the material. This steadies the punch and lessens the possibility of the punch moving before the blow is struck. In locating the intersection of two scribed lines, the point is placed in one of the lines and the punch is then moved along this line toward the intersection. In this manner you can feel, as well as see, when the point reaches the exact location. When the intersection is reached, the punch is brought to a perpendicular position without moving the point and a light blow struck with a light hammer. Prick punch marks should never be deep, as the location point may need to be changed. Also if they are deep, they are hard to polish out of the completed fitting.

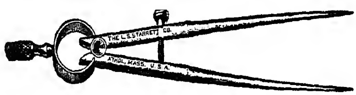
Automatic Punch Fig. II

Where considerable layout work is being done, an automatic prick punch is a great time saver, Fig. II. This punch is made with a hollow barrel in which a hammer, or striker, is held under spring tension. When the location is secured, a down pressure releases the hammer, thus marking the metal. The automatic prick punch gives a uniform mark each time and much of the danger of the punch moving before it can be struck with the hammer, is eliminated. It further adds to the speed of the work by requiring the use of only one hand.

DIVIDERS

Just as the compass is used for drawing circles or arcs on paper, the divider is used for drawing circles or arcs on metal. This is one of the greatest uses of dividers, especially in layout work. They are also useful in measuring distances between, or over surfaces, or for comparing distances or sizes with standards, such as those of a template or on a steel rule. They can be used to transfer any such distance to the material being worked.

Probably the best type of divider made is that which is manufactured for the tool maker. In this trade, the divider is constantly used and great accuracy is needed. These dividers have legs which are drawn to sharp tempered points, which retain their sharpness over a long period of time. These dividers are also especially sturdy to eliminate any possible weave in the legs, so that when they are used as a compass, a perfectly true, sharply defined arc or circle will result. While for the general layout work a less expensive type may be used, it will be found that the cheap dividers are very unsatisfactory. In the cheap grade dividers, considerable pressure is needed to scribe an arc or circle. This pressure will in turn blunt, or dull the points resulting in a broad, dull line. To prevent this requires constant sharpening which soon ruins the dividers.

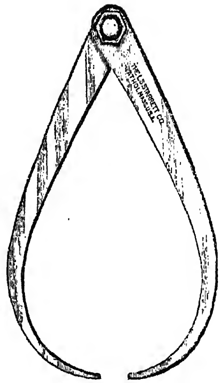


In using the dividers to scribe an arc on metal, it is held so that the thumb rests near the fulcrum. The first and second fingers are extended on the opposite side as far as possible down each leg. In this manner the fingers further reinforce the leg, to prevent any spring or weave. To scribe the arc, the leg which the second finger is supporting is used as a stationary center. The line is made by slightly inclining the divider in the direction of the rotation and making one firm stroke. If the divider is kept sharp, it will be unnecessary to trace over a scribed arc. In fact, it is undesirable to do so as a confusion of lines often results.

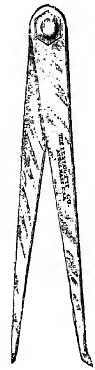
A complete list of simple layout problems in which the use of dividers is essential will be found on the sheet entitled Simple Lay Out Problems.

CALIPERS

Calipers are instruments or small tools for taking measurements of the inside or outside of curved objects where the use of a scale or tape would be difficult or would give inaccurate results. After the calipers are set so that they just fit the object, the dimension is taken from them with a scale. The following illustrations are supplied through the courtesy of the L. S. Starrett Co.



A - Outside



B - Inside

Fig.

There are several types of calipers. Where extreme accuracy is not essential, the type shown in Fig. I may be used, A for outside measurements and B for inside. Fig. II illustrates a combination inside and outside caliper, with one style screw adjustment.

Greater accuracy may be obtained with the spring bow type with screw adjustment, which is shown in use in Fig. III-A and B. Fig. IV illustrates the method of taking off the measurements, and also a slightly different type of screw mounting.

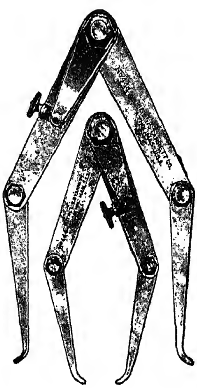
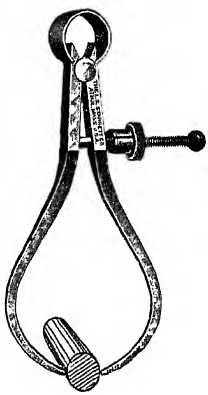
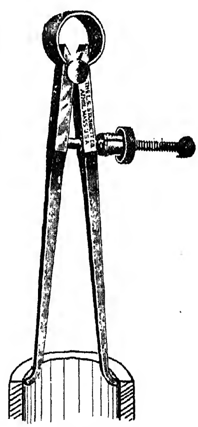


Fig. II

The hermaphrodite caliper shown in Fig. V is used for measuring the dimension from the edge of an object to some fixed point or line, and also for scrib-



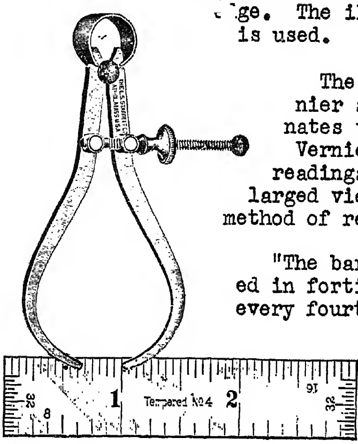
A - Outside



B - Inside

Fig. III

CALIPERS
(continued)



ing lines at a given distance from the edge. The illustrations show how it is used.

The caliper rule with Vernier shown in Fig. VI eliminates the use of a scale and the Vernier gives extremely close readings. Fig. VII gives an enlarged view of the Vernier. The method of reading it follows.

"The bar of the tool is graduated in fortieths or .025 of an inch, every fourth division, representing

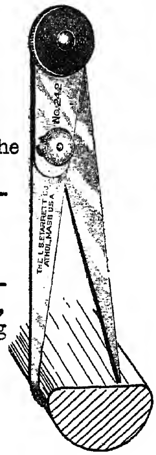


Fig. IV

Fig. V

a tenth of an inch, being numbered. On the Vernier plate is a space divided into twenty-five parts and numbered 0, 5, 10, 15, 20, 25. The twenty-five divisions on the Vernier occupy the same space as twenty-four divisions on the bar.

"The difference between the width of one of the twenty-five spaces on the Vernier and one of the twenty-four spaces on the bar is therefore 1/25 of 1/40 or 1/1000 of an inch. If the tool is set so that the 0 line on the Vernier coincides with the 0 line on the bar, the 0 line to the right on the Vernier will differ from the 0 line on the bar by 1/1000 of an inch; the second line by 2/1000 of an inch and so on. The difference will continue to increase 1/1000 of an inch for each division until the line 25 on the Vernier coincides with the line 24 on the bar.

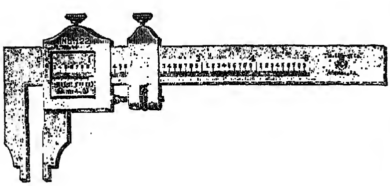


Fig. VI

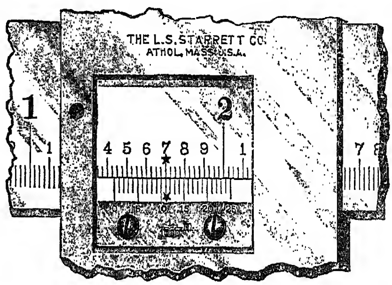


Fig. VII

CALIPERS
(continued)

"To read the tool, note how many inches, tenths (or .100) and fortieths (or .025) the 0 mark on the Vernier is from the 0 mark on the bar; then note the number of divisions on the Vernier from 0 to a line which exactly coincides with a line on the bar. EXAMPLE: In the illustration the Vernier has been moved to the right one and four-tenths and one-fortieth inches (1.425), as shown on the bar, and the eleventh line on the Vernier coincides with a line, as indicated by the stars, on the bar. Eleven-thousandths of an inch are therefore to be added to the reading on the bar and the total reading is one and four hundred and thirty-six thousandths inches, (1.436)."

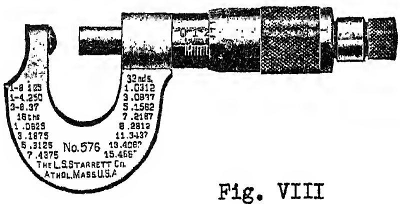
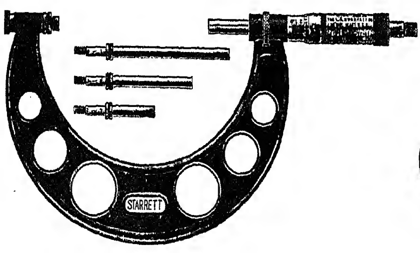


Fig. VIII

The micrometer shown in Fig. VIII is the most commonly used instrument for extremely accurate measurements. The one illustrated is equipped with a rounded anvil for measuring the wall thickness of tubing or other curved objects. The method of reading a micrometer is explained on the following pages.

Micrometers ordinarily measure only within the limits of an inch. Thus a one-inch "mike" will measure from 0 to 1", a two-inch will measure from 1" to 2", and so on. To eliminate the necessity of the mechanic's having so many sizes, some micrometers are made with interchangeable anvils, giving a wide range of use. Such a set is shown in Fig. IX. Fig. X shows a ratchet stop for micrometers. By using the small knob, the ratchet slips by the pawl when the proper degree of tightness has been reached, thus preventing damage to the frame or screw.



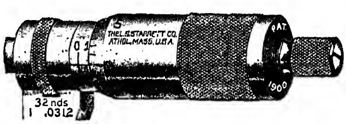
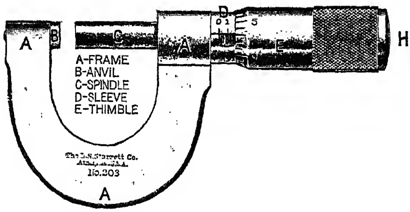


Fig. IX

Fig. X

HOW TO READ A MICROMETER CALIPER



A micrometer caliper is a device for making very accurate measurements. The illustration and instructions below are given through the courtesy of the L. S. Starrett Co., manufacturers of precision tools and instruments.

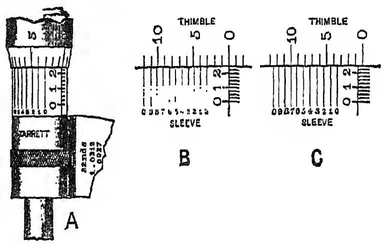
"The spindle C is attached to the thimble E, on the inside, at the point H. The part of the spindle which is concealed within the sleeve and thimble is threaded to fit a nut in the frame A. The frame being held stationary, the thimble E is revolved by the thumb and finger, and the spindle C being attached to the thimble revolves with it, and moves through the nut in the frame, approaching or receding from the anvil B. The article to be measured is placed between the anvil B and the spindle C. The measurement of the opening between the anvil and the spindle is shown by the lines and figures on the sleeve D and the thimble E.

"The pitch of the screw threads on the concealed part of the spindle is 40 to an inch. One complete revolution of the spindle therefore moves it longitudinally one fortieth (or twenty-five thousandths) of an inch. The sleeve D is marked with 40 lines to the inch, corresponding to the number of threads on the spindle. When the caliper is closed, the beveled edge of the thimble coincides with the line marked 0 on the sleeve, and the 0 line on the thimble agrees with the horizontal line on the sleeve. Open the caliper by revolving the thimble one full revolution, or until the 0 line on the thimble again coincides with the horizontal line on the sleeve; the distance between the anvil B and the spindle C is then 1/40 or (.025) of an inch, and the beveled edge of the thimble will coincide with the second vertical line on the sleeve. Each vertical line on the sleeve indicates a distance of 1/40 of an inch. Every fourth line is made longer than the others, and is numbered 0, 1, 2, 3, etc. Each numbered line indicates a distance of four times 1/40 of an inch, or one-tenth.

"The beveled edge of the thimble is marked in twenty-five divisions, and every fifth line is numbered from 0 to 25. Rotating the thimble from one of these marks to the next moves the spindle longitudinally 1/25 of twenty-five thousandths or one thousandth of an inch. Rotating it two divisions indicates two thousandths, etc. Twenty-five divisions will indicate a complete revolution, .025 or 1/40 of an inch.

HOW TO READ A MICROMETER CALIPER
(continued)

"To read the caliper, therefore, multiply the number of vertical divisions visible on the sleeve by 25, and add the number of divisions on the bevel of the thimble, from 0 to the line which coincides with the horizontal line on the sleeve. For example, as the tool is represented in the engraving, there are seven divisions visible on the sleeve. Multiply this number by 25, and add the number of divisions shown on the bevel of the thimble, 3. The micrometer is open one hundred and seventy-eight thousandths. (7 x 25 = 175 + 3 = 178)."



HOW TO READ A TEN-THOUSANDTHS MICROMETER CALIPER

"Readings in ten thousandths of an inch are obtained by the use of a Vernier, so named from Pierre Vernier, who invented the device in 1631. As applied to a caliper this consists of ten divisions on the adjustable sleeve, which occupy the same space as nine divisions on the thimble. The difference between the width of one of the ten spaces on the sleeve and one of the nine spaces on the thimble is therefore one-tenth of a space on the thimble. In engraving B the third line from 0 on thimble coincides with the first line on the sleeve. The next two lines on thimble and sleeve do not coincide by one-tenth of a space on thimble; the next two, marked 5 and 2, are two-tenths apart, and so on. In opening the tool, by turning the thimble to the left, each space on the thimble represents an opening of one-thousandth of an inch. If, therefore, the thimble be turned so that the lines marked 5 and 2 coincide, the caliper will be opened two-tenths of one-thousandth or two ten-thousandths. Turning the thimble further, until the line 10 coincides with the line 7 on the sleeve as in engraving C, the caliper has been opened seven ten-thousandths, and the reading of the tool is .2507.

"To read a ten-thousandths caliper, first note the thousandths as in the ordinary caliper, then observe the line on the sleeve which coincides with a line on the thimble. If it is the second line, marked 1, add one ten-thousandth; if the third marked 2, add two ten-thousandths, etc."

THE COLD CHISEL

The cold chisel is a tool for cutting unheated metal, hence the name "cold chisel". It has many uses, such as cutting rivet heads, cutting small bar or rod into rough sizes, chipping rough castings, cutting grooves, etc. Probably its greatest usefulness to the airplane mechanic is in shearing metal, or "roughing out" sheet stock preparatory to filing to size. The most proper chisel for shearing is the flat chisel, Fig. I.

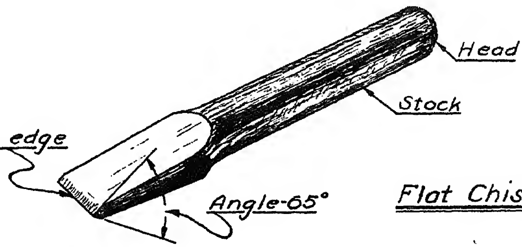


Fig. I

Flat Chisel

For general purposes the chisel is ground to a cutting angle of 65°. It may be necessary to increase the angle for very hard stock, but for soft material the angle should be less. The chisel should be as sharp as possible without being so sharp that the cutting edges dent in use.

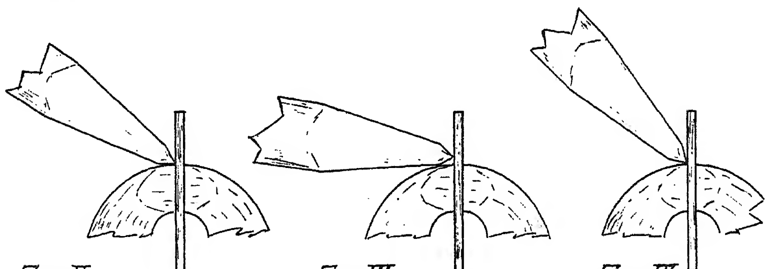


Fig. II Fig. III Fig. IV

In using the cold chisel for shearing, the material should be held in an upright position in the vise and the chisel held so that the cutting edge and the jaws of the vise are parallel, Fig. II. In this manner the chisel and the vise jaws act as a shear, producing a smooth cut. If the head of the chisel is held too low, as in Fig. III, the shearing action is lost and the material is either bent or torn off. When the head of the chisel is held too high, the chisel will cut into the vise, Fig. IV. To improve the shearing further, the chisel should be held at an angle to the material, as in Fig. V so that a "slicing" cut results.

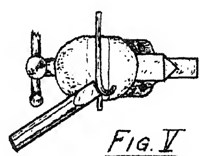


Fig. V

THE HACK SAW

The hack saw is a hand tool for sawing metal. It differs from he wood saw in that it has a replaceable blade held by an open rame, Fig. I. The teeth on the blade are smaller, harder and are set" differently from those on a wood saw.

The hack saw has a wide range of uses, s it can be used to saw wood, metal, fiber, ard rubber, and many other similar mater-als ranging in size from heavy steel bars o thin sheet material. Its uses include ne sawing of nails, bolts, wire, tubing, ar stock, sheet stock, etc.

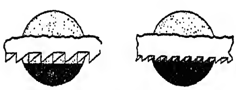
Fig. I

To get the best results from using the hack saw for its var-ous jobs, much care should be paid to the correct selection of the blade. For general use a 12" blade will give better results than a shorter blade as it permits a longer stroke. It may be necessary, however, to use a shorter blade where space is limited. Likewise a blade having 24 teeth to the inch will give good results for general work.

Suggestive Diagrams

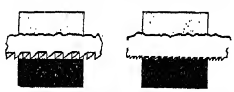
Importance of selecting Hand Hack Saw Blades with proper number of teeth for cutting various metals:

14 Teeth Per Inch, for Softer Metals, Large Sections

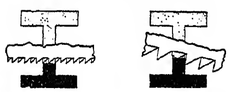


Plenty of Chip Clearance — Fine Teeth. No Chip Clearance. Teeth Clogge

18 Teeth Per Inch, for Tool Steel, High Carbon and High-Speed Steel

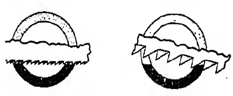


4 Teeth Per Inch, for Angle Iron, Brass, Copper, Iron Pipe, Etc.



Coarse Teeth Straddles Work Stripping Teeth

2 Teeth Per Inch, for Conduit and ther Thin Tubing. Sheet Metal Work



In selecting the proper point blade, it should be remembered that generally speaking, coarse teeth cut faster, and in using the fine tooth blade there is less danger of the teeth breaking. By refer-ring to the chart in Fig. II, the correct blade may be determined quickly. Hack saw blades have rip saw teeth, which are bent outward on opposite sides to give the blade a sawing clearance. Every third tooth is straight to serve as a raker or cleaning tooth.

In assembling a hack saw as in Fig. III, the blade should be put in the frame with the teeth pointing forward. The blade should be tightened firmly in the frame to lessen the risk of the blade breaking. In sawing, the pressure should be applied on the forward stroke and the saw raised slightly on the return stroke to avoid "rounding" the teeth. If the space permits, each stroke should be made the entire length of the blade, using a slow, even pressure of not over 60 strokes per minute.

Ordinarily, material to be sawed is held in a vise as shown in Fig. IV. How-ever, in sawing thin material a much bet-ter job can be done if the material is clamped flat on the bench with the portion

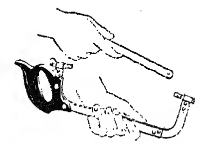
THE HACK SAW
(continued)

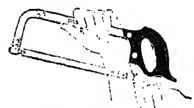
to be cut extending beyond the edge. By using a fine tooth blade and holding the saw at a very flat angle to the material, a smooth cut will result.

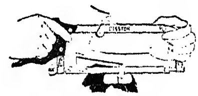
The airplane mechanic often has to use the hack saw in places where the space is very limited. A more convenient saw for use in close quarters is the narrow frame hack saw shown in Fig. V. A saw of this type is also more convenient to carry in the tool box.

It is sometimes possible to remove broken studs by sawing a screw driver slot in the broken end of the stud shank and removing with a screw driver. Where it is necessary to do this type of work, or where it is desirable to remove considerable metal in a cut, it is often convenient to use a hack saw fitted with two blades instead of one. This will give a true cut the thickness of the two blades.

In sawing thin wall tubing the teeth of the hack saw will last much longer if the pressure is applied on the back stroke and released on the forward stroke. The same effect may be accomplished by holding the hack saw backwards and sawing as usual.


How to Insert Blade in Hack Saw Frame


How to Tension Blade

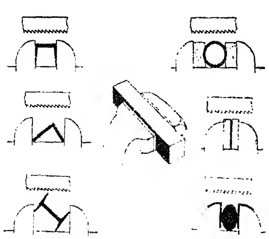

How to hold a Hack Saw Frame when Saw

; III

Soft tubing may be cut without binding the blade or flattening the tube by first inserting a wood dowel of the correct size to fit the tube.

Holes may be cut from the inside of material by drilling a large starting hole, inserting the hack saw blade and re-assembling the saw. The blade may be faced in any one of four directions in reference to the frame, in a manner very similar to the coping saw. For special work a hack saw having a much deeper frame is made. With this saw it is possible to take a wider cut.

How to Hold Work in Vise



Above are suggestions for clamping irregular shapes. To hold oval or circular work in square jaw vise, use wood, leather, or copper filler pieces to grip work and to prevent scarring.

FIG. V

STON •

FILES

The file is one of the most universally used tools. While it is made primarily for use on metal, it can be used with equal success on many of the composition materials, such as hard rubber, fiber, etc. Files are used for every type of cut from the very rough cut, where removing excess material quickly is the main objective, to a cut so fine as to be almost polishing. To fit such a large variety of needs the file itself is made in many shapes and cuts. To attempt to explain

Tang

the uses and characteristics of all the types of files would be almost impossible, but a general conception of the varied use of the file can be learned from the fact that one large file manufacturer makes more than 250 styles and more than 1,000 different cuts and sizes of files.

Blade

most common shapes of files are the flat, half round, mill, round, square and the triangular shaped file, called the three-square, or three-cornered file. Probably the most widely used shape is the flat file,

"Cut" refers to the kind of teeth on a file. The single cut file has but one course of chisel shaped grooves, running diagonally across the blade, forming the teeth. The double cut file, in addition to the single cut teeth, has a second finer course

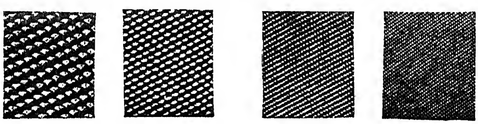
Point

of chisel grooves crossing the first, forming diamond shaped teeth. The rasp cut file, used on wood or other soft material, has individually cut teeth which are made by raising the metal with a punch. Each of the three types of cuts are supplied as standard in four grades, the rough cut, bastard cut, second cut and smooth cut, as shown below.

SINGLE CUT

Rough Cut　　Bastard Cut

DOUBLE CUT



Bastard Cut　　Second Cut

RASP CUT

Bastard Wood Rasp　　Second Cut Cabinet　　Smooth Cabinet

Courtesy of Henry Disston & So

FILES
(continued)

Hints in Using a File:

ver use a file without a handle, as to
the palm of your hand or wrist if th
also permits a better grip, insuring
Make sure the handle is tight on the

slow, stroke, using the entire length of the

3. As the file teeth point forward, the file cuts the forward stroke. On the return stroke the file e raised slightly to prevent dulling the teeth

Note: In filing soft material such as alumi
the file should be drawn back over the
cleaned on this stroke.

5. The material to be filed should be held firmly to prevent the file from chattering on the work.

6. Use enough pressure on each stroke to keep the file engaged in the cut, thereby avoiding glazing the file by slipping.

7. When filing sheet metal held in a vise, do not allow the material to extend far beyond the jaws of the vise, as this will allow the material to vibrate.

8. Use a file brush and card to clean the choked gullets between the teeth.

9. In using a round file, a smoother cut will result if the file is rotated slightly on the forward stroke.

10. To avoid cutting hollows in the material when using the round or half round file, a slicing motion should be used on the forward stroke.

11. Small rod or bar stock may be cut by nicking the material on opposite sides with the corner of a file and then bending the material.

12. The file is essentially a cutting tool and should be considered as such. It should not be thrown with other tools or allowed to become rusty. The file should never be hammered or used as a pry, as the blade is very brittle and will break easily.

DRILLING METAL

The metal twist drill is used for drilling holes in metal. See Fig. I. For general all around purposes, this drill is ground to an angle of 59°, but for harder metal the angle is less, and for softer metals the angle is greater. For further information see the sheet on Grinding Drills. The carbon steel drill is a soft, inexpensive drill and although satisfactory for drilling wood and soft metals, it will burn when hard metal is drilled, especially if it is turned rapidly. For hard metals, a more expensive high speed drill is used.

g. I

An electric drill such as shown in Fig. II is used where possible in drilling holes. This drill consists of a small, portable electric motor with a drill chuck attached. This is preferred to the hand drill in Fig. III, as it is much faster and easier to operate. There are many places however, where a hand drill is indispensable. For heavier work where the electric drill is not available, a larger hand operated breast drill is used, Fig. IV. For special work in small places such as corners in the fuselage or hull, a long flexible shaft, driven by an electric motor, is used to turn the drill. The drill is sometimes held at right angles to the shaft, much in the same manner as a dentist's drill.

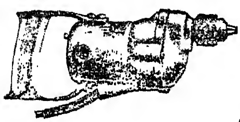


FIG. II

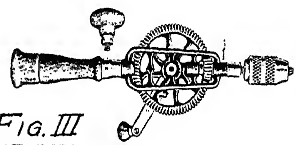


FIG. III

Drills - Courtesy of Air Associates

The prick punch used in the metal layout does not make a very large hole, therefore a center punch, having a heavier point, must be used to provide a guide hole for the drill. The guide hole serves two purposes. It prevents the drill from "walking" or slipping away from the desired location, and allows the cutting lips of the drill to touch the metal. If a guide hole is not made, it is difficult to start the drill in hard metal unless an extreme amount of pressure is used. This pressure is likely to break the drill or dent the material, especially if it is thin stock. In drilling large holes in thick metal, a small guide hole should be drilled first, as this assures a more truly centered hole as well as a faster job. In heavy work the drill should be kept cool with light cylinder oil.

For drilling holes in heavy metal a drill press is used. This is a large power driven machine, and is therefore seldom found except at a factory or a repair station. Where it is necessary to drill a large hole in heavy metal using only a hand electric drill, or a breast drill, it is easier to drill several holes, increasing the diameter of the drill used each time until the desired size is reached.

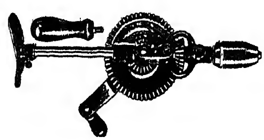


FIG.

SHARPENING DRILLS

There is a tendency on the part of a beginning mechanic to overlook the importance of sharpening drills. The twist drill is essentially a cutting tool and should be treated as such. To understand thoroughly how to sharpen a drill, something should be known of the functions of the various parts of a drill. As with the reamer, the drill may be divided into three parts; the point, the shank and the body. The point of the drill is considered to include the entire cone-shaped tip. The point contains the cutting edges or cutting lips, Fig. I. The shank is the portion by which the drill is turned. The body contains two spiral grooves on opposite sides running from the shank to the point, called "flutes".

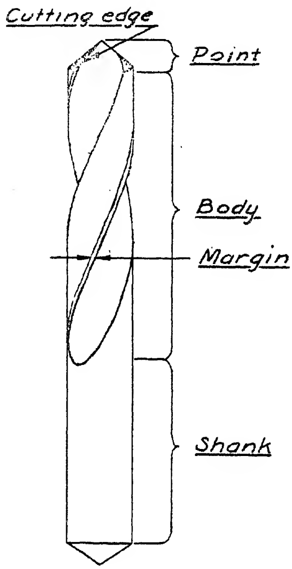


FIG. I

The flutes of a drill serve not only the purpose of forming the cutting edges of the point but are designed to curl the chips (metal shavings cut by the drill) tightly within themselves, to avoid clogging the hole. Channels are also formed by the flutes whereby the chips may escape from the hole. Another function of the flutes is to allow lubrication to reach the point.

If the entire body of the drill were the exact diameter of the drill itself, much pressure would be needed to overcome the resultant binding of the body on the sides of the hole. This would cause the drill to become heated to the point of drawing the temper from the drill. To avoid overheating, all of the body of the drill is of less diameter, except a small "margin" on the cutting side of each flute. This is called body clearance.

For general purposes the drill is sharpened to the angles shown in Figures II and IV. If the lip angle is more than 59° it is hard to center the drill, as the flatter angle gives the drill a tendency to walk or slip. An angle of less than 59° on the lips causes the drill to cut less rapidly as the cutting edges are longer. The cutting lips should always have a clearance of from 12° to 15° to allow the lips to penetrate into the metal. This is an important point, for unless the drill is ground with clearance here, the surface back of the cutting edge will rub on the bottom of the hole and will not permit the lips to cut. This should be

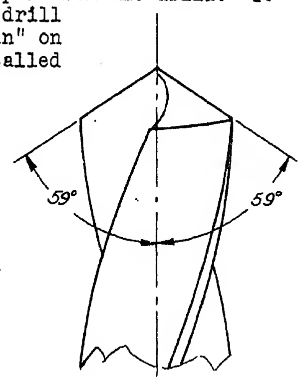


FIG. II

SHARPENING DRILLS
(continued)

watched closely in grinding drills as it is very easy to overlook this, especially on drills of small diameter.

Drills should be ground on a fine emery wheel that is surfaced truly. Care should be taken to prevent the drill from getting hot, by dipping it in water frequently while grinding. Grinding drills is not a difficult process, but it requires considerable practice. One of the best ways to learn to sharpen drills correctly is to select a medium size drill, about 3/8" in diameter, and practice sharpening this drill several times. If a drill of much smaller diameter than this is used in practicing, it will be difficult to check the angles. This might result in learning an improper method.

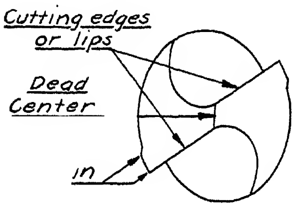
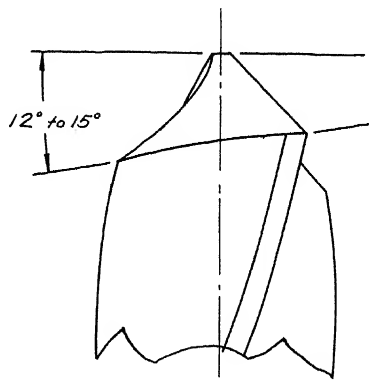


FIG. III

A metal template with the correct angles will be found to be of great assistance in checking the accuracy of your work. The drill should be held in the right hand and supported near the point with the first finger of this hand. Holding the shank of the drill with the left hand, let the point come into contact with the face of the stone in such a manner that the cutting edge is at right angles with the emery wheel. This will give the lips their angle. By moving the left hand down, the drill pivots over the first finger of the right hand and as the drill point moves upward, the lip clearance is cut.

The cutting angle of 59° has been found to be the best angle for use in drilling such materials as chrome molybdenum, cold rolled steel, tin, cast iron, wrought iron, fiber, etc. For drilling soft materials such as brass, aluminum, dural, etc., the drill should be sharpened to a lip angle of approximately 50° as this permits the drill to cut faster. For drilling wood, an even smaller angle is used. In drilling thin sheet stainless steel, a drill with an angle of about 65° is recommended. If this angle is used, greater care must be taken to provide a good center punch or guide hole for the drill, as it is harder to center the blunt point.



IV

THE REAMER

Unless a twist drill is ground perfectly, the resulting hole will be slightly eccentric or slightly oversize. For this reason it is almost impossible to drill a dependably true hole. In certain important fittings such as the hinge fittings, landing gear fittings etc., it is essential that the bolt holes be the exact size to prevent any play or lost motion. In order to be assured of a perfectly true hole, a reamer is used.

I

The reamer consists of three parts; the body, the shank and the blades. The shank has a square tang to allow the reamer to be held in a tap wrench, or other similar handles, for turning. The main purpose of the body, of course, is to support the blades.

The blades on a reamer are made of steel, hardened to such an extent that they are very brittle. For this reason great care must be taken in using and storing the reamer in order to protect the blades from chipping. When a hole is being reamed, the reamer should be turned in the cutting direction only, to prevent chipping or dulling of the blades. Great care should be used to assure even, steady turning, otherwise the reamer will "chatter", causing the hole to become marked or scored. To prevent damage to the reamer while not in use, it should be wrapped in an oily cloth and kept in a box.

Reamers of the types shown in Figures I and II can be purchased in any standard size, but are also available in size variations of .001" for special work. Where a number of holes of the same size are to be reamed a solid straight flute reamer is used, as it lasts longer and is less expensive than the expansion reamer.

The solid spiral flute reamer, Fig. II, is used also where many similar holes are to be reamed and is preferred by many mechanics as it gives better results. The spiral reamer costs slightly more than the straight flute reamer.

FIG. III

For general purposes, an expansion reamer, Fig. III, is the most practical. This reamer is usually sold in standard sizes from 1/4" to 1" by 32nds and is designed to allow the blades to expand 1/32". For example the 1/4" expansion reamer will ream a 1/4" to a 9/32", and a 9/32" reamer will carry the hole from 9/32" to 5/16". This range of adjustment allows a few reamers to cover the entire field and by using them carefully they will meet almost any need.

Reamers are supplied in two materials; carbon steel, and high speed steel. Generally speaking, the cutting blades of a high speed reamer lose their keenness quicker than a good carbon steel reamer, but after that keenness is gone it will last longer than the carbon reamer before it is beyond average use.

SHAPING METAL FITTINGS

The shaping of metal fittings may be divided into two steps: roughing out, or removing the excess metal, and dressing, or filing to size. In roughing out, the chief aim is to remove the excess metal in the quickest and easiest way. The method used is largely determined by the shape of the fitting. If the fitting has only straight lines and rounded corners, it can be either sheared with a cold chisel or sawed with a hack saw.

Generally speaking, material can be cut faster with a cold chisel than with a saw. However, if the chisel is used, at least 1/16" must be left for dressing. This is because the shearing starts microscopic fractures in the edges of the metal which must be removed by filing. It is possible to saw to within 1/64" of the layout line with safety, therefore even though the actual sawing takes longer, less time is required for dressing. If the fitting is more complicated, having inside curves, sharp angles, slots, etc. a metal coping saw, similar to a jeweler's saw can be used to advantage, especially if the metal is not over 1/16" thick.

The simple fitting shown in Fig. I may be roughed out either by shearing or sawing, as indicated. A saw should be used to rough out an angle, Fig. II. For a long "inside curve" or concaves, both the saw and the chisel should be used, Fig. III.

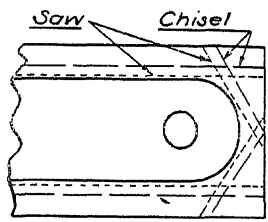


FIG. I

In roughing out slot cuts the drill can be used to advantage, as shown in Fig. IV. To cut out large or irregularly shaped holes from the interior of a fitting, a drill is really essential. This can be done by drilling a series of small holes as shown in Fig. V, and cutting the material between the holes with a small chisel. Another method is to drill a series of overlapping holes. If this is done the chisel is not required, but it is a more difficult process and must be laid out with greater accuracy. To do this the holes are laid out so that the distance between the center punch marks is slightly less than the diameter of the drill. The cut is made by drilling alternate holes, first hole number one, hole number three, five, etc., and then drilling the connecting holes.

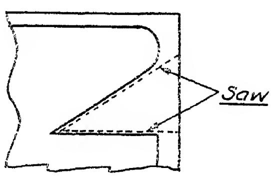


FIG. II

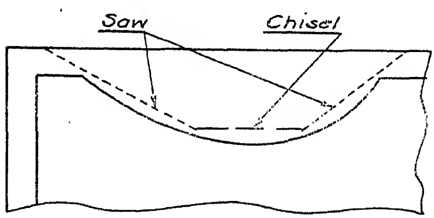


FIG.

SHAPING METAL FITTINGS
(continued)

If an attempt is made to drill the holes consecutively, the drill will slip back into the adjoining hole, destroying the center for the hole that is being drilled and possibly breaking the drill.

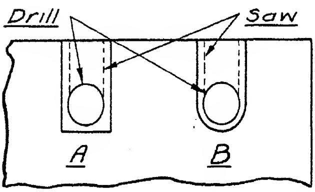


FIG. IV

After the fitting has been roughed out it must be dressed to size. The fitting should be held in a vise that has been equipped with soft jaws to prevent scarring the fitting. The material should be clamped firmly to prevent it from "chattering" while being filed. If it is necessary to remove much material, a bastard cut file should be used. For dressing a fitting of the type shown in Fig. I, an 8" or 10" flat file will do the entire job. In filing a sharp angle of 30° or less as in Fig. II, a cape file will be needed. For further information on this and other types of files, see the page on "Files".

For inside curves on fittings, a half round file is used, Fig. III. Here again the bastard cut file is used to remove metal quickly, and the cut should be finished with a second cut file. In using the half round file, care should be taken to prevent small hollows in the curve. This can be avoided by filing with a sliding or slicing motion and rotating the file a little from left to right on each stroke.

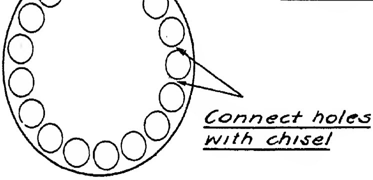


FIG. V

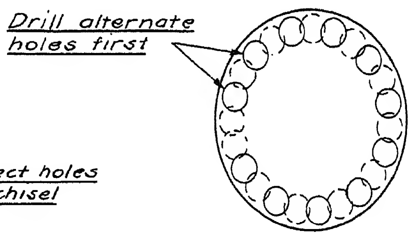


FIG. VI

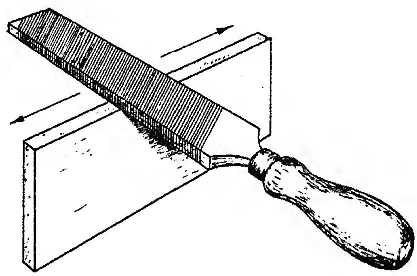
For places similar to the one shown in Fig. IV-A, a flat file of the correct size will do the work. A better procedure would be to dress the bottom of the cut with the edge of a flat file and then dress the sides, using a safety edge file. This would prevent any possibility of cutting the bottom of the slot deeper while the sides are being filed. The half round file can be used in dressing inside holes, Figs. V and VI. For dressing an inside curve of small radius, a round file should be used.

FINISHING METAL FITTINGS

Finishing metal fittings consists of draw filing and polishing. This is done for two reasons; to remove any possible burrs and fractures, and to improve the appearance.

One of the most important features to be considered in the finished fitting is its strength. The strength will be seriously impaired if the fitting is left with any file marks remaining on the edges or surfaces, as the load and the constant vibration will deepen file marks or fractures, possibly to the point of causing the fitting to fail.

The fitting should be draw filed before any bend is made. To do this the material should be held firmly in a smooth jawed vise and filed with a smooth flat file held in the position shown. The file should be held in both hands and the stroke should be rapid but firm. Care should be taken not to let the file slice or move diagonally across the edge, as will be the tendency due to the diagonally cut file teeth. As all cross file marks and cuts disappear, the weight of the stroke should be lessened and the speed increased to give the edge a polish. As metal can be removed quite rapidly in this manner, the layout lines must be watched carefully. The file should be held exactly at right angles to the fitting so that a true edge results. Never allow the file to rock, as this will cause rounded edges. Fittings should never have rounded edges unless so specified in the working drawing. Before the fitting is removed from the vise the square point of the file should be run along each edge to remove any burrs left along the corners by the draw filing.



Draw filing

The surfaces of the fitting are now ready for emery cloth. Medium emery cloth should be used to remove the layout lines, followed with very fine emery cloth for polishing. If it is desirable to put a high polish on the fitting, a few drops of oil can be put on the emery cloth. This prevents the emery from scratching. A very fine grade of steel wool will add further to the polish. To give a high polish to the edges a small strip of fine emery cloth can be held around a file and the edges polished in the same manner as draw filing.

Burrs should be removed from every hole, usually with a flat file. In doing this the file will bend some of the burr into the hole; therefore, the hole should be cleaned out by running a drill through it again, or by using a reamer. It is a good practice to fit the correct size bolt to each hole to make sure the hole has sufficient clearance for the bolt, thereby avoiding difficulty when installing the fitting.

BENDING FITTINGS

Sheet metal of almost any thickness when not in a heat-treated or hardened condition, may be bent cold without damage provided it is bent over a properly rounded corner. In trade terms, this rounded corner would be referred to as a radius of bend or bending radius, and is illustrated by "R" in Fig. I. In the case of steel, the radius should be at least as much as the thickness of the material for cold bending. That is, R = T. If the steel is heated to a bright red, the radius may be smaller. The radii for various aluminum alloys are given in the table below. However, difficulty will be experienced in cold bending material more than ¼" thick by hand or by hammering in a vise.

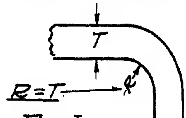


FIG. I

RADII REQUIRED FOR 90° BEND IN ALUMINUM ALLOY,

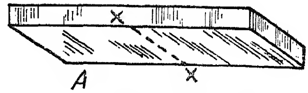
IN TERMS OF THICKNESS, T.

B&S Ga. Inch Inch	Approximate Thickness 26 0.016 1/64	20 0.032 1/32	14 0.064 1/16	8 0.128 1/8	5 0.189 3/16	2 0.258 1/4
2S-0 3S-0 51S-0 53S-0	0	0	0	0	0	0
		(No Radius Required)				
2S-½H 17S-0 A17S-0 24S-0	0	0	0	0	0-1T	0-1T
A17S-T 51S-W 53S-W	0-1T	½T-1½T	1T-2T	1½T-3T	2T-4T	2T-4T
53S-T	½T-1½T	1T-2T	1½T-3T	2T-4T	3T-5T	4T-6T
17S-T	1T-2T	1½T-3T	2T-4T	3T-5T	4T-6T	4T-6T
17SR-T 24S-T	1½T-3T	2T-4T	3T-5T	4T-6T	4T-6T	5T-7T
24SR-T 51S-T	2T-4T	3T-5T	3T-5T	4T-6T	5T-7T	6T-10T

(17S-T and 24S-T can be bent over smaller radii immediately after quenching.)

BENDING FITTINGS
(continued)

In addition to using the proper radius, due allowance must be made for the expansion and contraction of the material at the bend. This is known as the bending allowance and may be understood by reference to Fig. II.



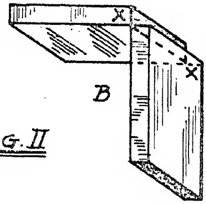


FIG. II

If a piece of flat material such as that shown in (A) is bent along a line x----x, its tendency is to break, as shown in (A). In fact, if the material were brittle or lacked ductility, as a piece of glass or highly hardened spring steel, it would break. In the case of metal, particularly if it is annealed or reasonably soft, one side (the outside) stretches, and the other, or inside, contracts. The amount of material allowed for the bend is indicated by the cross-hatched portion in Fig. III, which shows a normal bend. It is customary to give dimensions, such as D and E, to the point where the bending radius, or the curvature, begins. The amount of material used up in the bend, or the bending allowance (B.A.) is calculated by the formula: B.A. = C^{o} (.01743R + .0078T) where C is the angle of bend in degrees, R is the radius and T the thickness of the material. If the dimensions D' and E' are given as in Fig. IV, the amount of the radius must be deducted from each when drawing the flat pattern of the fitting. (The flat pattern shows how the part appears before it is bent.)

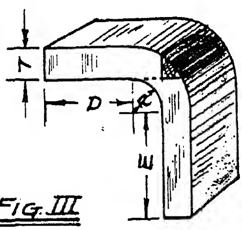
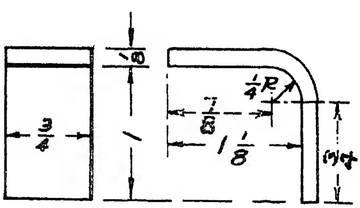


FIG. III

Illustrating by a practical example, assume that the flat pattern of the piece shown in Fig. V is to be laid out. Since the dimensions 1-1/8" and 1" in the side view are given to the faces, the radius must be deducted, leaving 7/8 for the horizontal dimension and 3/4 for the vertical, as indicated by the dotted lines and figures. The bending allowance, since the bend is through 90^{o}, is $90^{o}\left[(.01743 \times \frac{1}{4}) + (.0078 \times 1/8)\right]$. (It is often more convenient to use decimal equivalents for the



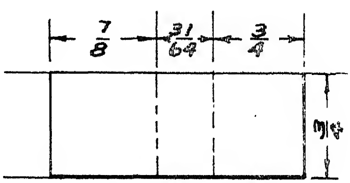


FIG. V

BENDING FITTINGS
(continued)

fractions, as .25 for $\frac{1}{4}$ and .125 for 1/8. In this case, however, the fractions are simpler.) Completing the calculation, the B.A. is .48, or 31/64. To lay out the flat pattern, first draw lightly two parallel lines 3/4 apart as in Fig. VI, then a vertical between them near one end. At a distance of 7/8 from the vertical draw a broken line, and 31/64 from that, another broken line. The distance between the broken lines is the B.A. Draw another vertical 3/4 from the second broken line and the layout is complete.

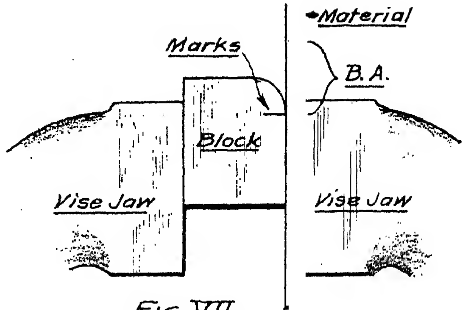


FIG. VII

Sheet metal should be bent across the "grain." It may seem peculiar that metal should have a grain but if a smooth sheet of cold-rolled stock is closely examined, it will be noticed that there are fine lines left by the rolls. These indicate the direction of the grain. Bending lines should be marked with a pencil instead of scratching them in with a scriber, even when layout out steel. If the material is aluminum, the scriber positively must not be used, as a crack is sure to develop along the scratch.

Bends should always be made over a smooth, steel bending-block, with the corner filed to the proper radius. Needless to say, the vise used should have smooth jaws, at any rate where it is in contact with the piece being bent. This is illustrated in Fig. VIII.

When the material is clamped in the vise with a bending block of proper radius (1/4" in the case just discussed), the bottom bending line should lie at the point of tangency of the side of the block with the radius, or, in other words, at the point where the radius begins. To simplify the alignment, this point may be marked on the end of the block and the bend line marked on the edge of the material with a pencil. The procedure is illustrated in Fig. VII. Care should be observed to keep the bending lines parallel to the top surface of the bending block.

By using a wide bending block, a U-shaped part of any reasonable depth can be made. See Fig. VIII. This illustrates not only the

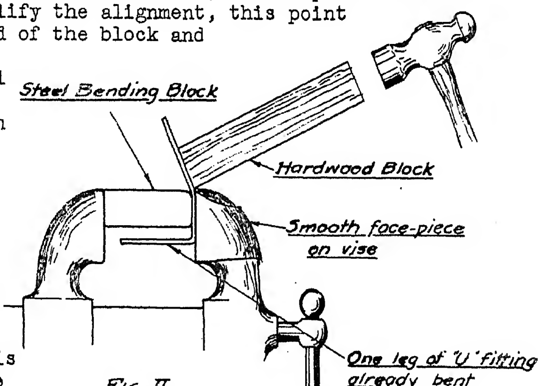
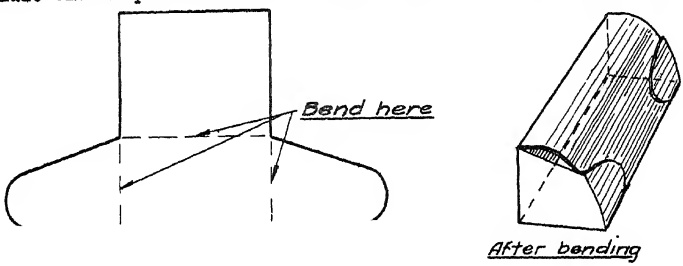


FIG. II

BENDING FITTINGS
(continued)

use of the bending block but also the proper procedure in bending sheet stock, particularly dural or aluminum. If soft materials, such as the latter, are struck with a steel hammer, they will always show the hammer marks, and the same is true to a lesser extent, of steel. If it is necessary to strike the metal direct, without the block shown, a mallet made of wood, lead; or rawhide weighted with lead, should be used.

If the vise which is being used does not have smooth jaws, and most vises do not, a face piece should be made of aluminum or brass, similar to the type shown in Fig. IV. This prevents marring the part being made and helps to insure a workman-like job. See Fig. III.



In clamping material in the vise, care must be taken that the bending lines are exactly parallel to the top of the vise jaw and to the bending block. This may often be determined (depending on the shape of the piece being bent) by putting a small steel square on the top face of the bending block and squaring up the center line.

If it is necessary to make sharp bends or double curves in steel, the metal should be heated with a torch to a bright red. In this case it is permissible to use a steel hammer. Such work is usually done only on parts which are to be welded, and the shaping and welding are part of the same operation. An illustration is the gusset plate at a tubing joint such as that shown in Fig. IV.

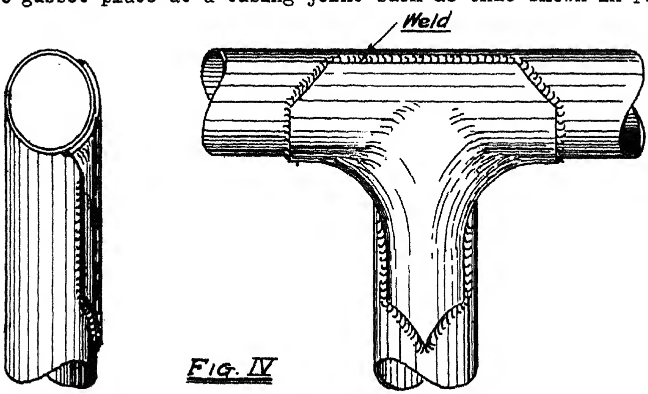
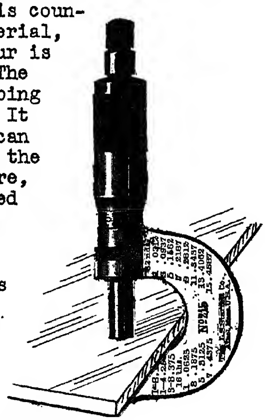


FIG. IV

TABLE OF METAL GAGES

Gage No.	B. & S.	Roebling	B.W.G.	U.S.
1	0.289	0.2830	0.300	0.281
2	0.258	0.2625	0.284	0.266
3	0.229	0.2437	0.259	0.250
4	0.204	0.2253	0.238	0.234
5	0.182	0.2070	0.220	0.219
6	0.162	0.1920	0.203	0.203
7	0.144	0.1770	0.180	0.188
8	0.128	0.1620	0.165	0.172
9	0.114	0.1483	0.148	0.156
10	0.102	0.1350	0.134	0.141
11	0.091	0.1205	0.120	0.125
12	0.081	0.1055	0.109	0.109
13	0.072	0.0915	0.095	0.094
14	0.064	0.0800	0.083	0.078
15	0.057	0.0720	0.072	0.070
16	0.051	0.0625	0.065	0.062
17	0.045	0.0540	0.058	0.056
18	0.040	0.0475	0.049	0.050
19	0.036	0.0410	0.042	0.0438
20	0.032	0.0348	0.035	0.0375
21	0.0285	0.0317	0.032	0.0344
22	0.0253	0.0286	0.028	0.0312
23	0.0226	0.0258	0.025	0.0281
24	0.0201	0.0230	0.022	0.0250
25	0.0179	0.0204	0.020	0.0219
26	0.0159	0.0181	0.018	0.0188
27	0.0142	0.0173	0.016	0.0172
28	0.0126	0.0162	0.014	0.0156
29	0.0113	0.0150	0.013	0.0141
30	0.0100	0.0140	0.012	0.0125

The matter of various gages is likely to be extremely confusing to one who is not thoroughly familiar with them. There are four different systems in common use in this country at present, and in buying or using material, one should be certain just which of the four is being used with the particular material. The Browne & Sharpe (B. & S) is used in describing aluminum and dural sheet and copper wire. It is also sometimes referred to as the American wire gage. The Roebling, sometimes called the Washburn and Moen, is used in measuring wire, such as the tinned piano wire sometimes used for internal bracing. Tubing and ordinary steel sheet is usually listed in the Birmingham wire gage (B.W.G.), sometimes called the Stubs'. Stainless steel sheet comes in U.S. standard gage, as a rule. There are several others, but these four are the most common. The thickness of sheets should be measured with a micrometer held inside of the edge, as illustrated, as there is likely to be a burr on the edge which will spoil the accuracy of the measurement.

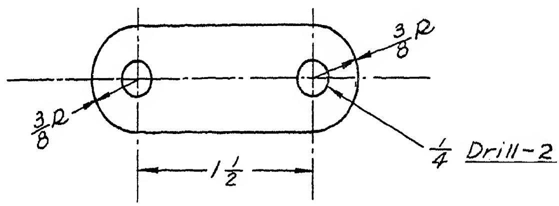


HOW TO MAKE A WASHER PLATE

This fitting is designed to provide a simple introduction into the use of the layout tools. Also this fitting is designed to fit into the wing section as a washer plate for the drag wire fitting.

MATERIALS: Stock sheet, cold rolled steel, 1/16" x 1" x 2"; fine emery cloth.

TOOLS: Rule, scriber, dividers, prick punch, hammer, center punch, cold chisel, second-cut and smooth flat files, 1/4" drill.



WASHER PLATE

PROCEDURE:

1. Using the rule as a straight :e, scribe one firm, sharp center line.
2. Locate and prick punch the hole locations.
3. From the prick punch marks, scribe two 3/8" arcs.
4. Complete the outline by drawing lines tangent to these arcs.
5. Center punch and drill the 1/4" holes.
6. Clamp the metal in a smooth jawed vise and cut to within 1/16" of the outline. Read instructions on shearing with a cold chisel.
7. Remove the excess metal, using the second-cut file.
8. Remove the burrs from the drilled holes.
9. Draw file the edges to remove any fractures, using smooth file.
10. With the smooth file and emery cloth, polish the fitting until no traces of the scribed lines or burrs remain.

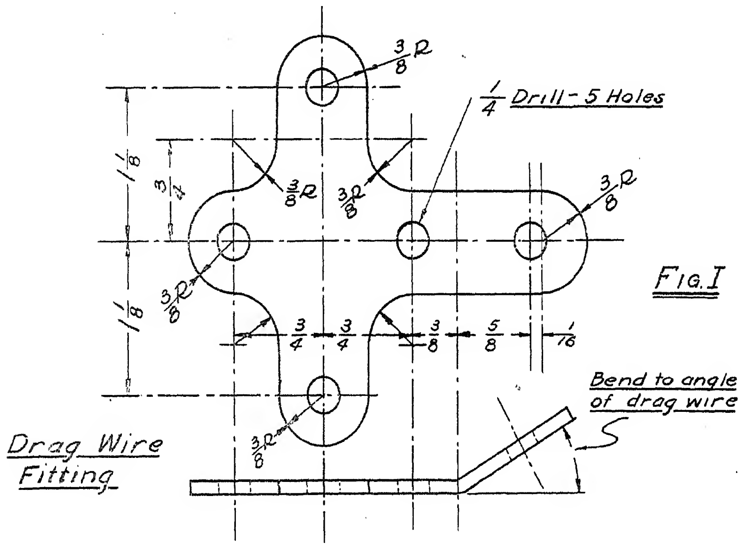
Note: Two of these fittings will be needed for the model wing section.

HOW TO MAKE A DRAG WIRE FITTING

This drag wire fitting is designed to be used on the tip compression member of the wing section. It is bolted to the spar with two 1/4" bolts. Two lugs are bent to form right angles with the fitting, making a U-shaped anchorage for the compression tube. The single lug is bent to the angle of the drag wire. As the load from the drag wire is more concentrated at the end of this lug, it is reinforced with additional material at this point. This is done by making the arc eccentric with the hole. In this fitting the eccentricity is 1/16".

MATERIAL: Sheet stock, cold rolled steel, 1/16" x 3-1/2" x 3-3/4"; fine emery cloth.

TOOLS: Layout tools, center punch, 1/4" drill, flat and half round files, hack saw, mallet.



PROCEDURE:

1. Scribe the 3-3/4" centerline.

2. Measure in from one edge of the metal approximately 1-1/4" and mark this location on the centerline.

3. Erect a perpendicular centerline from the 1-1/4" mark.

4. Using the dividers and steel scale, locate and prick punch the centers for all holes and arcs.

5. Scribe the arcs, using a 3/8" radius as shown.
   Note: It will be noticed that the 3/8" arcs are tangent to each other at one end of the fitting.

HOW TO MAKE A DRAG WIRE FITTING
(continued)

6. Scribe lines tangent to the arcs as shown in the flat layout drawing, Fig. I.

7. Locate and mark with pencil the bending lines.
   Note: Bending lines should never be marked with a scriber as the scribe line starts a fracture at the bend.

8. Center punch for the holes and drill all holes to 1/4" diameter.

9. Using the hack saw and files, cut and dress the material to size.

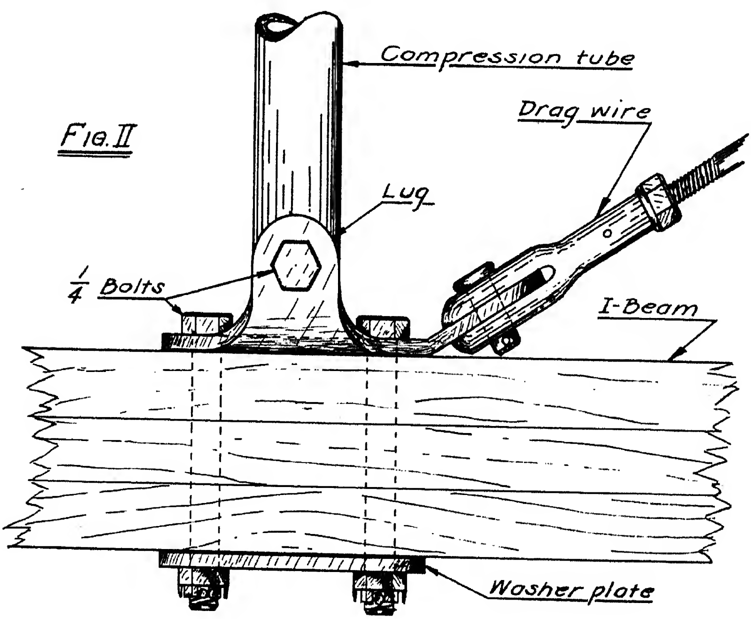
10. Draw file the edges with a smooth file to remove any possible fractures.

11. Clamp the fitting in a smooth jawed vise and bend the wire lug to the angle of the drag wire with the wood mallet. Fig. I.

12. Bend the lugs for the compression tube to right angles with the fitting. Fig. II.
    Note: For information on bending metal, see the sheet on that subject.

13. Check the right angle lugs to make sure the holes are in line and that the space between the lugs is exactly 3/4".

14. Remove the burrs and polish the entire fitting.



HOW TO MAKE A HINGE FITTING

The fitting described here can be used as a hinge fitting on the model wing section. This fitting was designed to give practical experience in many phases of fitting work. It calls for the shaping of square corners, small fillets, inside curves and lines tangent to arcs, as well as the cutting out of an inside hole of irregular outline. It illustrates the use of eccentric hinge pin holes and the drag wire lug made as a part of the fitting.

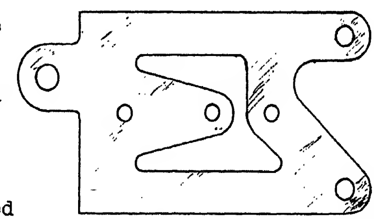
While the directions below are for making only one hinge fitting, if the model wing section is being built, four of these fittings will be necessary. Two of these fittings will not require the wire lug.

MATERIAL: 1/16" Cold rolled steel, 4" x 8"; fine emery cloth, fine steel wool.

TOOLS: Metal layout tools; drills, 1/8", 1/4", 5/16", 3/8"; hack saw; 1/8" cape chisel; flat files, half round files, 3/16" round file.

PROCEDURE:

1. Scribe a lengthwise center line on the metal.
2. Scribe a line on one end of the metal parallel to the centerline and 1/2" above it, then measure in slightly over 1/2" and prick punch this location. This will give the location of the hinge pin hole as shown in Fig. II.
3. Referring to the dimensional drawing, locate and prick punch the centers for all the arcs.
4. Connect the arcs with scribed lines.



Hinge Fitting   Fig. I

5. Erect a perpendicular to the center line at a point 1/2" in from the hinge pin location, and mark the distance of 1-1/2" on each end of this line, from the centerline.
6. Scribe lines from these location marks to the respective 3/8" arcs at the strap end of the fitting.
7. Mark the bolt hole locations and drill with the correct size drill.
8. To cut out the irregularly shaped hole, drill a series of 1/8" holes, making sure that each hole is within the layout lines. These holes should be as close together as possible. For more specific directions see the sheet on "Shaping Metal Fittings". Complete the cut by connecting the holes with a chisel.

HOW TO MAKE A HINGE FITTING
(continued)

9. Rough out and dress the fitting to size. To do this the flat, half round and round files will be required.

10. Dress the fitting by removing all burrs from the bolt holes and draw filing the edges.

11. Clamp the fitting in a smooth jawed vise so that the radii at the bottom of the lug are even with the vise jaws, and using a wood block, bend the lug to the angle of the drag wire fitting, or approximately 35°, Fig. III.

12. Polish the fitting with fine emery cloth and steel wool.

If a set of four hinge fittings are being made, two of the fittings must have the lugs bent in opposite directions, forming a left and right hand fitting. As the other two fittings are to be used on the outside of the beams, they should be made without lugs. This may be done by simply connecting the radii at the bottom of the lug with a tangent line, thus cutting out the lug entirely and giving a larger lightening hole.

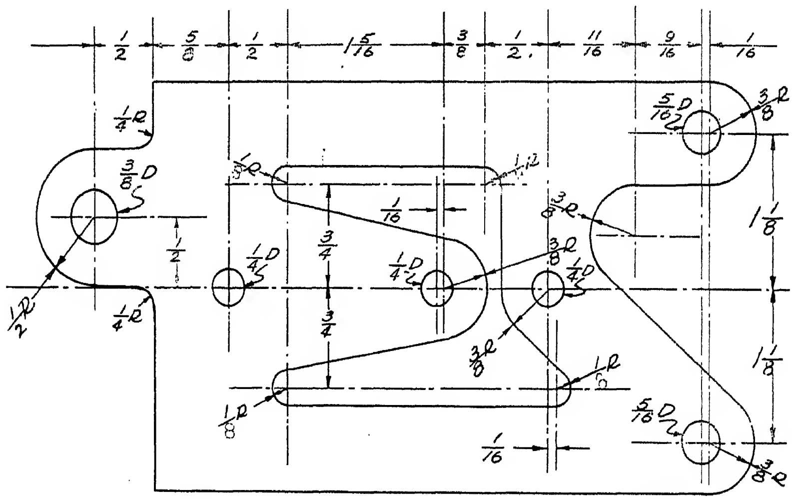


FIG. II

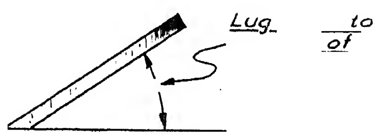
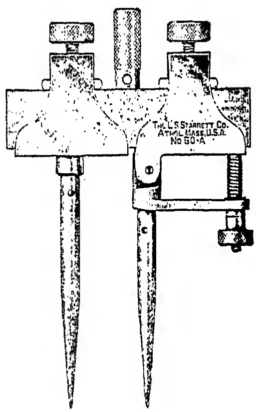


FIG. III

SHEET METAL LAYOUTS

In factories, sheet metal layouts are usually made from blueprints the same as is done in fitting layouts etc. They differ, however, in the respect that they are usually much larger, therefore more cumbersome to handle. The ordinary layout tools are not practical for sheet metal layouts. The tools required are similar to the ordinary layout tools, but are on a larger scale.

The 6" steel scale is replaced with the 2', 4', 6', and sometimes even a 10' or 12' steel rule. Where accuracy is important, a hardened steel straight-edge of lengths up to 12' or 16' is used. Dividers can be used for the smaller circles or arcs, but for cir-



Trammel points

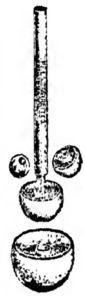
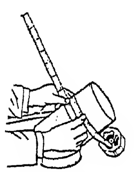


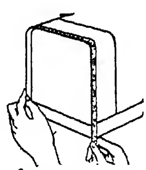
FIG. I

Courtesy L.S. Storrett Co.

cles outside of the range of dividers, a trammel bar is sometimes used. The trammel bar is also used for transferring distances from the scale to the work or for comparing distances from a standard, such as a template or the original piece, to the work. It consists of a bar, usually of hardwood, of any convenient length, to which two movable trammel points have been fitted. By loosening the thumb screw, the trammel point can be moved to any desired location. The point on the right side of the trammel bar in Fig. I is equipped with a vernier so that by turning the bottom nut a finer adjustment can be made. Where it is necessary to make a measurement from the center of a hole, the left hand trammel point can be equipped with a ball point, which centers the point in the hole.



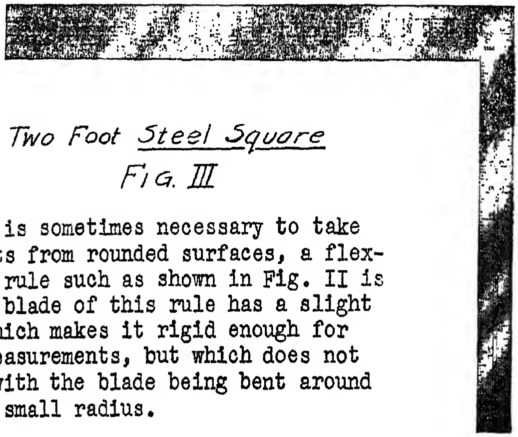
When tightly stretched around a cylinder, a "Pull-Push" Rule will measure the circumference as accurately as a steel tape.



One measurement takes the place of three.

FIG. II

SHEET METAL LAYOUTS
(continued)



Two Foot Steel Square
Fig. III

As it is sometimes necessary to take measurements from rounded surfaces, a flexible steel rule such as shown in Fig. II is used. The blade of this rule has a slight concave, which makes it rigid enough for straight measurements, but which does not interfere with the blade being bent around objects of small radius.

A 2 ft. steel carpenter's square is also found quite useful in sheet metal layouts, as it can often be used to erect perpendicular lines, square corners, lay out angles, etc., Fig. III.

The airplane mechanic on the field does considerable work in sheet metal, such as replacing cowling, making fairings, air scoops, small tanks, etc. Where this type of work is being done, it is rare indeed to find the mechanic furnished with anything more than a rough sketch. This calls for not only ingenuity on the part of the mechanic, but a working knowledge of the simple layout methods as well. For instance, where an air scoop is being made, it may be necessary to know how to lay out a flat pattern of a cone. In making a tank, it may be essential to know how to develop a flat pattern of an ellipse, or the intersection of a cylinder with a plane or curve. The correct methods for making these layout developments will be found on the following pages. If the principles involved are learned thoroughly they can be applied to a great variety of jobs.

In fitting cowling, windshield frames, fillets, etc., much time and material will be saved if thin sheet tin or even heavy cardboard is used, to get an idea of how and where to cut the material to be used. The tin or cardboard is cut to fit, and then may be flattened and used as a template, making allowances where necessary for seams, fittings, beadings, etc.

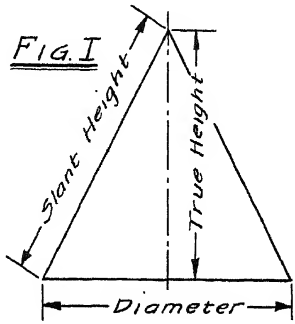
HOW TO LAY OUT A CONE

A cone or a section of a cone is often used in such places as air scoops, heater pipes, etc. The pattern for a cone is sometimes secured by rolling stiff cardboard to shape and cutting it to fit with scissors. When the cardboard is unrolled, an approximate pattern will result. This is a quick method and in many cases will prove to be sufficiently accurate.

To make a cone of specific dimensions, much time may be saved by making or developing the geometric layout.

To lay out a cone, two dimensions must be known; the diameter and the slant height, Fig. I. Very often the dimensions given for a cone include only the diameter and the true height. If only the true height is given, the slant height may be found by solving for the hypotenuse of a right triangle. One-half of the diameter squared plus the true height squared equals the slant height squared. For instance, to find the slant height of a cone whose diameter is 6" and whose true height is 4":

FIG. I



Let X = Slant height, then
$3^2 + 4^2 = X^2$; $9 + 16 = X^2$. X would then equal the square root of 25, or 5.

Knowing the correct dimensions, draw a full size circle representing the diameter of the circle, Fig. II. Draw an arc whose radius is equal to the slant height. The length of the arc should be equal to the circumference of the circle. The distance may be stepped off with the dividers. After the correct length for the arc has been found, lines should be drawn from these points to the center for the arc. This will give the cone layout. Additional material, sufficient to make the necessary flanges for the seam, should be allowed. Flanges are shown by dotted lines in Fig. II.

NOTE: The smaller the units used in stepping off the distance of the arc, the more accurate the result will be.

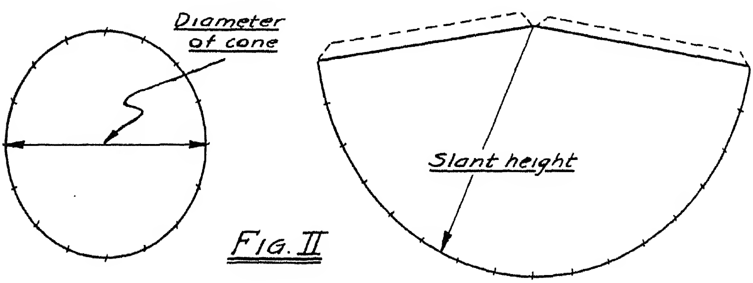


FIG. II

HOW TO LAY OUT AN ELLIPSE

An ellipse is a flattened circle or an oval shape. The length of the ellipse is called the major axis, while the width is called the minor axis. The construction of an absolutely accurate ellipse is a difficult operation, but for general purposes either of the two methods given here will be satisfactory.

To construct an ellipse, draw a centerline of the desired length for the major axis, and bisect this line with a perpendicular. On the perpendicular line mark off the desired minor axis, as in Fig. I.

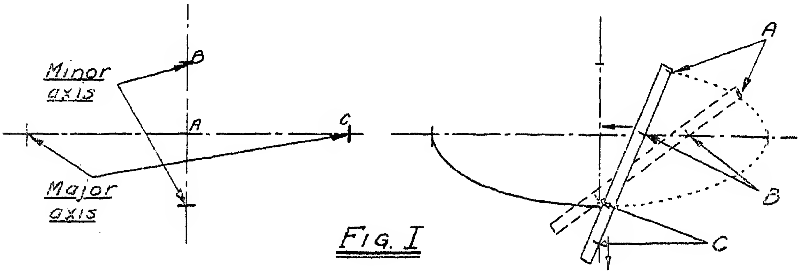


FIG. I

Select a suitable straight edged batten or a strip of celluloid, and place a point near one end and label it "A". Make a second point, "B", so that the distance from A to B is equal to one-half the minor axis. Make a third point, "C", so that A - C is equal to one-half the major axis, Fig. I.

Keeping the point B always on the major axis line, and the point C always on the minor axis line, the point A will scribe an ellipse as the batten is rotated. The path of point A can be marked with a series of small dots and these dots connected to form the outline of the ellipse, Fig. I.

A method of constructing a curve similar to an ellipse is shown in Fig. II. Where a true ellipse is not required this method can be used satisfactorily, especially on large work or where only one-quarter or one-half of the shape is needed. A rectangle is constructed. having for its width the minor axis and for its length, the major axis. The length is divided into any even number of parts and the width is divided into the same number of parts. The lines are then connected as shown in Fig. II.

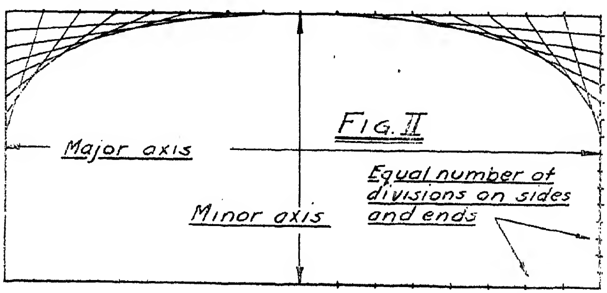


FIG. II

HOW TO DEVELOP AN INTERSECTION

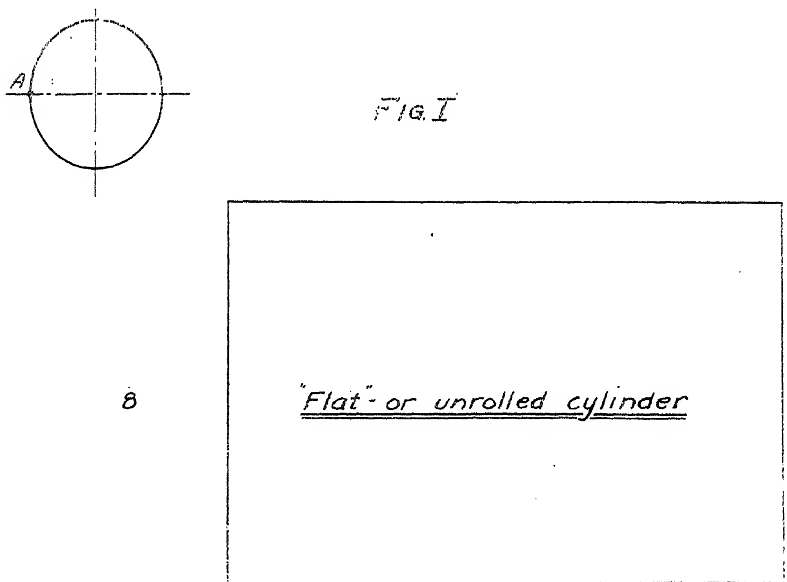
As was explained previously, it is sometimes necessary for the airplane mechanic to lay out the flat pattern of a cylinder intersecting a flat surface or plane at an angle. The directions given here are for developing the flat pattern of a 2" cylinder intersecting a plane at an angle of 30°. This example is used as it fits the requirements for the filler pipe on the tank described under "How to Build a Tank".

By substituting various angles and shapes, this method of development can be used to find the flat pattern of a streamline or oval shape section, intersecting planes of various angles, or a curved surface such as the side of a round tank, etc.

The development is made full size on a large sheet of paper, preferably stiff drawing paper, then the flat pattern cut out and the outline traced on the material. Much time will be saved if the drawing is made with the aid of a drawing board T square and triangle.

1. The development consists of three drawings bearing the correct relation to each other. On the left hand side of the page a full size side view drawing of the cylinder is made, in this case a 2" cylinder, 8" long. Directly above the side view, on the same centerline, a cross section view is drawn which will be a 2" diameter circle. To the right of the side view will be a rectangle representing the cylinder unrolled. See Fig. I.

FIG. I

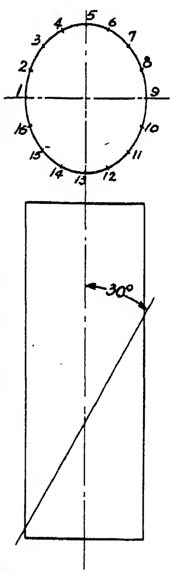


HOW TO DEVELOP AN INTERSECTION
(continued)

2. The side view of the cylinder is then cut with a line representing the angle the cylinder intersects the plane, in this case at 30° to the centerline.

3. The circumference of the circle (or cross section drawing) is divided into an even number of parts starting at point A on Fig. I. The circle should be divided into at least 16 parts, the distances being stepped off with the dividers. Starting with point A as number one, number the points consecutively.

4. With the dividers set at the circle divisions, step off an equal number of divisions on the top line of the "flat" drawing. The division points should be numbered to correspond to the numbers on the circle, starting with number one on the left. As there will be 17 points to 16 divisions, number the 17th point #1, as in Fig. II. Draw vertical lines from each of these points to the bottom of the drawing.



5. Draw vertical lines from each number on the circle to the angle line on the cylinder and number these intersections to correspond to the numbers on the circle.

5 6 7 8 9

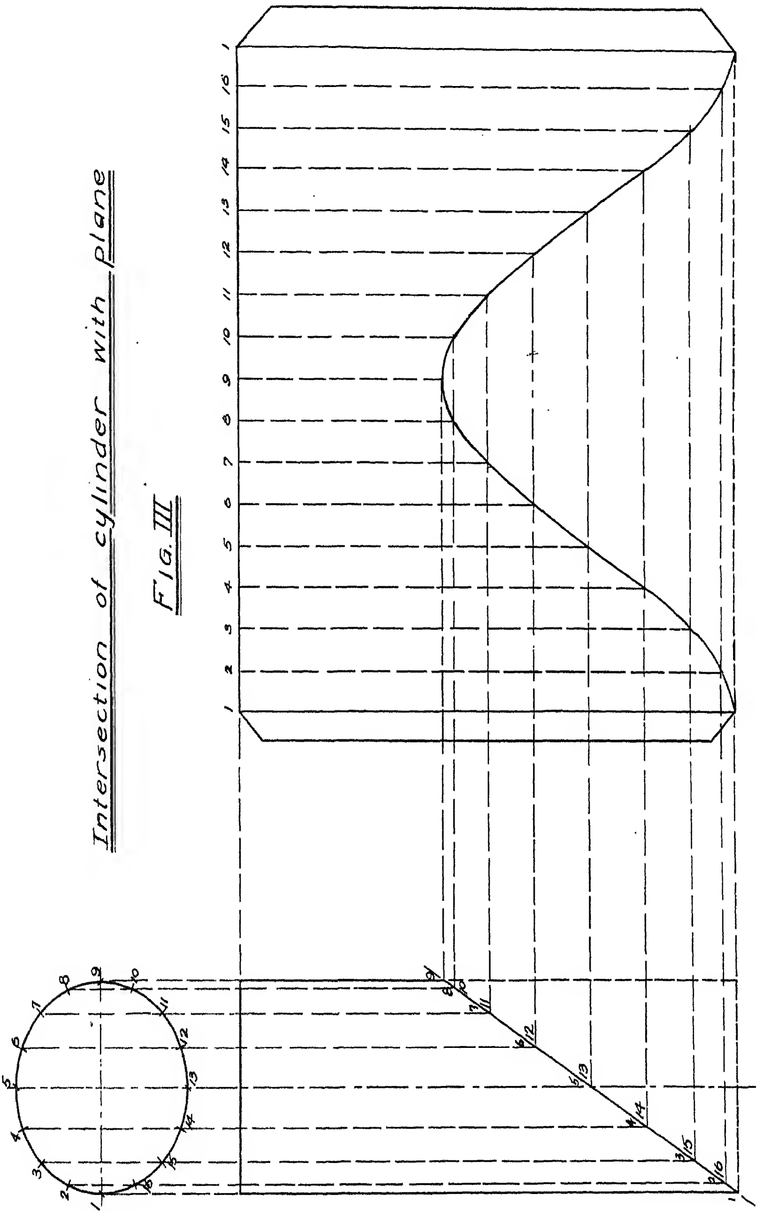
6. Transfer the distances from the top of the cylinder to the angle line, to each line of corresponding number on the flat drawing. This may be done by extending a line from the intersection point to the correct vertical lines with the T square.

7. The correct distance on each vertical line should be marked with a small dot.

8. Connect the dots with a true curved line. For ordinary purposes this can be done accurately enough free hand. Greater accuracy can be obtained by the use of a French, or ship's curve.

is to be the true layout of the cylinder, a flange of be allowed on one end and a 1/2" flange on the other, for seam, Fig. III.

HOW TO DEVELOP AN INTERSECTION
(continued)

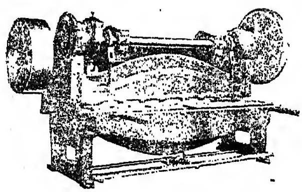


Intersection of cylinder with plane

FIG. III

CUTTING SHEET METAL

In factories where large sheets of metal are being cut to various sizes and shapes, this work is done with machines. For cutting a portion of metal from the width or from the length of a large sheet, a squaring shear is used. This is a machine which has two long hardened steel blades that slide past each other, cutting the metal with a shearing motion. The blades are usually from 4' to 12' long and it is possible to make a straight cut of this distance in one stroke.

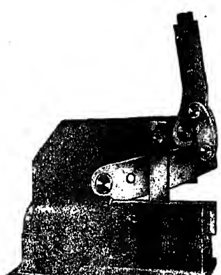


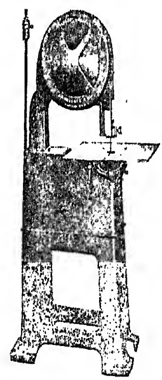
Pexto Squaring Shear

A smaller variation of the squaring shear is found in the hand operated bench shear. The bench shear has blades similar to the squaring shear but the length of the blade is usually from 4" to 8". While this device is convenient for cutting smaller sheets, it is impractical to attempt to cut curves with the bench h

For cutting curves in metal, a metal band saw of the type shown is often used. This machine is practically the same as the band saw used for wood. The difference lies in the blade, which has teeth similar to those on a hack saw blade. Where it is necessary to cut small irregularly shaped pieces from metal such as fittings, etc., a power machine called the "nibbler" is used in many factories. This machine punches a series of overlapping holes as the material is fed past the punch. By swinging the material as it is being fed into the machine, almost any shape can be cut.

As these machines are usually not available to the airplane mechanic, he has to depend on the cold chisel, hack saw and tin snips for cutting sheet metal. These tools are described on the following pages.

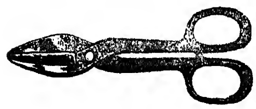




Shear

TIN SNIPS

The tin snip is a hand tool used for cutting light gauge sheet metal such as aluminum, dural, copper, terne-plate, etc. It is indispensable in cowling work, tank construction and general sheet metal work. The tin snip itself is just a big pair of scissors for cutting metal.



In cutting straight lines, the straight snips of the type shown in Fig. I are used. As the tin snip cuts by shearing, no material is taken away by the cut, as is done with the hack saw. When the cut is being made, the metal must curl out of the way to allow the snips to pass through the cut. The left hand side of the metal curls up and the right hand side curls down. As the material to be cut is often in large sheets, which necessitates it being placed on the floor or a large bench, the cut should always be made from the left hand side of the sheet, as this allows the scrap material which is being cut off, to curl up. This is essential as the large sheet, being on the floor, cannot curl down.

The straight snips can be used to cut outside curves, if the cut is made from the left to the right, allowing the scrap material to curl up. For general all around purposes, however, the airplane mechanic finds the circular snips more useful. It is slightly more difficult to cut a straight line with the circular snips, but with this tool it is possible to cut both outside and inside curves of small radius. Fig. II shows the circular snips.

Inside holes may be cut with the tin snips by starting the snips in a "V" cut made with a cold chisel. The cut on an inside hole should be made from the right to the left, as shown in Fig. III. As much of the material as possible is cut out in the manner shown. The material is then trimmed out of the corners after the middle portion is out of the way.

Note: Wire should never be cut with tin snips, as it is very easy to nick the hardened steel blades by doing so.

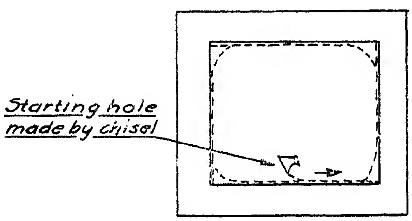


FIG. III

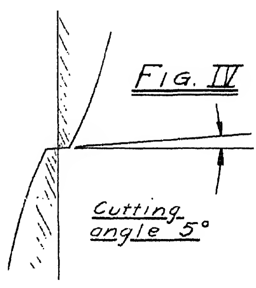


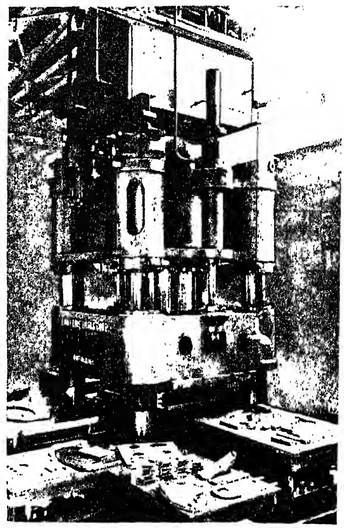
FIG. IV

SHAPING SHEET METAL

Sheet metal is playing an ever increasing part in aircraft construction. The advantages of sheet metal construction have long been recognized, but due to the expense involved in designing and installing the necessary equipment, it has been slow to reach its present stage of development. With the advent of larger airplanes, manufactured on a production basis, the high initial investments in sheet metal shaping machinery has been justified by the elimination of hundreds of hours of hand labor.

The relation between machine work and hand labor can easily be understood if you attempt to picture any large automobile manufacturers resorting to hand labor to shape fenders, hoods, etc.

An ever increasing number of aircraft manufacturers are using large hydraulic and mechanical hammers and presses to form sections from sheet metal. Many parts are being used that are stamped out with a large punch press. Much of the rolling, corrugating, beading, etc., that was formerly done by hand or with the aid of small hand equipment is now being done by machinery.



COURTESY LAKE ERIE ENGINEERING CORP.

2500 TON SINGLE ACTION HYDRAULIC PRESS FOR HIGH PRODUCTION BLANKING, DRAWING AND FORMING

FIG. I

The fabrication of sheet metal parts by machinery is an intensely interesting subject with which the airplane mechanic should become familiar. We are more interested here, however, in the repair and duplication of these parts by hand as these are the duties of the mechanic. While it is almost impossible to duplicate some of the machine fabricated parts, it is possible in a great majority of cases to repair them satisfactorily.

Parts which have to be formed or shaped are usually made from aluminum alloy, although any soft metal can be used. Sheet copper can be formed readily, but, as it is comparatively heavy for its strength it is not used to any extent in aircraft. Stainless steel can be formed if it is in the annealed state, however the forming is usually done by presses and drop hammers, as any excessive hammering of this material will cause it to harden rapidly. Many types of aluminum alloy have to be annealed before they can be formed without cracking, as previously explained in the section on "aluminum."

Probably the simplest process in the shaping of sheet metal is bending it in one dimension. This can be divided into two general classifications: bending to curves, and bending to angles. Small

SHAPING SHEET METAL
(continued)

sheets of metal can be bent to curves by hand, using a round pipe of the proper diameter as a mandrel or bending block. The procedure followed is similar to that employed in bending fittings to a radius.

To bend a small sheet of metal to a curve by hand the first step is to select a bar, rod, or tube having the same radius as that of the inside of the curve or bend desired. Next a line should be scribed on the outside of the tube, parallel to its axis. This can be done with a steel scale equipped with key seat clamps, Fig. II. If this method cannot be used, the same effect can be obtained by clamping a length of angle iron on the tube so that the tube rests in the open or V-shaped portion. A line scribed along the edge of one flange will be straight and parallel to the axis of the tube. Note: The tube should be inspected and any rough or uneven spots removed by filing, or finishing with emery cloth, to avoid scratching the material being bent.

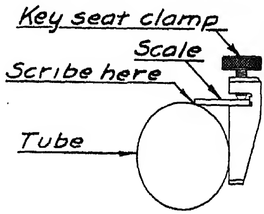


FIG. II

After the bending mandrel has been prepared, the bend lines should be marked on the material. Note: Scribed lines should not be used to mark any bend lines. Ordinary black pencil can be used, but a good red lead pencil will make a more readily distinguishable line on most metals. Not only the center line of the bend should be marked, but also a line indicating its beginning.

A wide board or other similar flat object should be secured and placed on the side opposite the bend lines. Next, the bending mandrel should be clamped in the vise or other suitable support. The material being bent and its backing should be clamped to the tube in such a manner that the beginning bend line exactly coincides with the line previously scribed on the tube. Note: If it is essential to avoid all scratches a large sheet of paper should be placed on both sides of the metal.

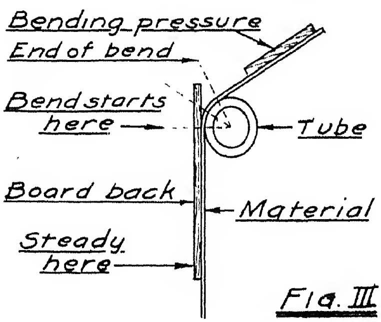


FIG. III

After the material has been backed and clamped in position the loose end may be bent until the line marking the end of the bend rests on the tube. This is illustrated in Fig. III. If the material has any tendency to spring back it will have to be bent beyond the desired curve, and if it is very springy it will have to be bent over a smaller mandrel so that when the bending pressure is released

SHAPING SHEET METAL
(continued)

the sheet will assume the correct shape. Just how much smaller the bend will have to be will be determined by experience.

When actually making the bend the hands should be spread out so as to cover as much of the sheet as possible, thereby exerting a more equal pressure and avoiding any small kinks on the free end. If the sheet is too large to do this satisfactorily a smooth board can be placed on the sheet and the bend made by pressing on the board. Where the material is quite heavy or a large sheet is being bent it may be necessary to secure the lower end of the backing board so that less pressure will be needed to prevent the tube clamps from slipping. Excess pressure at this point will dent the sheet where it touches the pipe.

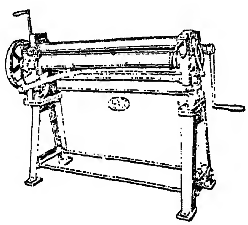


Fig. IV
PEXTO ROLLER (Courtesy Pexto)

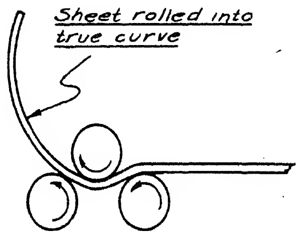


Fig. V

For bending large sheets to curves, a roll forming machine or "roller" such as shown in Fig. IV is used. This machine has three rolls arranged as shown in Fig. V. The rolls are geared together in such a manner that they turn in the direction shown when the hand crank is operated. By adjusting the space between the bottom rollers, and the tension on the top roller, a curve of the desired radius can be obtained. Soft materials should be protected on both sides by large sheets of wrapping paper to prevent any scratching. The top roller can be completely released at one end and raised so that the material can be slipped out of the machine at any desired time.

In addition to curving, metal forming rollers can be used to a limited degree in straightening sheet metal. Small bends and dents which are almost impossible to remove by hand can be removed from sheet material unless the metal is too thin or hard.

BENDING ANGLES IN SHEET METAL

Bending a narrow flange on a small sheet of material presents no difficulty, however if a large flange must be bent, considerable precaution must be taken to prevent the material from becoming distorted. It is best to do this work in a cornice brake, but if no brake is available its action can be somewhat duplicated by clamping two steel bars along the top and bottom of the bend line and forcing the extended portion to the desired angle by applying pressure to it evenly with a smooth board, or with an iron bar. If an attempt is

SHAPING SHEET METAL
(continued)

made to hammer the extended portion into position, a distortion or twisting of the metal is almost sure to result. When making a bend in this manner the inside clamping bar must have the corner next to the bend line rounded to the correct radius. Of course, this will not be necessary if only a slight bend is to be made.

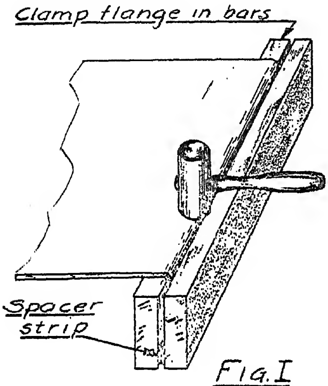


Fig. I

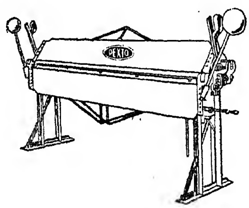
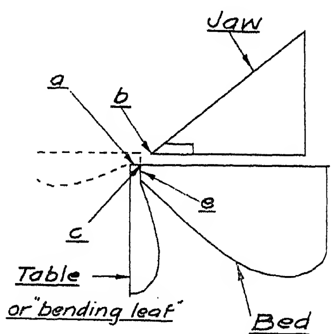


Fig. II
BRAKE - Courtesy Pexto

It is very difficult to bend hard material in the manner just described without causing the material to twist or curl. Better results will be obtained by reversing the procedure, as shown in Fig. I. Here the flange portion is clamped between the bars and the large sheet is bent. If a sharp angle is needed the sheet can be hammered against the inside bar with a wood or rawhide mallet. The inside bar should, of course, first have the bending corner rounded to the correct radius. This method does not stretch the metal to any appreciable extent unless an excess of hammering is done.

Angle bends in sheet metal should preferably be made in a bending brake, one type of which is illustrated in Fig. II, for much time will be saved and a better job will be made. The brake consists essentially of three parts; the bed, the jaw, and the table (Fig. III).



The bed is stationary and has a level top surface. The jaw can be moved up and down by hand levers and can be adjusted in the horizontal plane by means of adjusting screws. The table is hinged to the bed in such a manner that when it is in its down position the surface "a" is level with the surface of the bed

SHAPING SHEET METAL
(continued)

and when it is moved upward the corner "c" remains in the same position. The dotted lines show the position of the table after it has been raised 90°. It is possible to move the table through about 135°.

To use the brake the jaw is raised and the sheet to be bent is slipped in between the bed and the jaw. After aligning the bend line on the material with the corner of the jaw, the sheet is clamped in place by lowering the jaw. Bends are made by raising the table, or "leaf." As the table rises, the surface "a" forces the material up, bending it at the point "b".

The horizontal adjustment of the jaw depends upon the thickness of the metal being bent and the radius of the bend desired. It is important that this adjustment be made properly, as otherwise the material being bent may be seriously damaged. For example, if material 1/16" thick were being bent and the point "b" were adjusted so that it was 1/16" from the surface "e" and a 90° bend made, a cross section of the bent material would be similar to that illustrated in Fig. IV. Obviously the

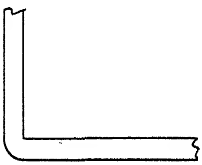


FIG. IV

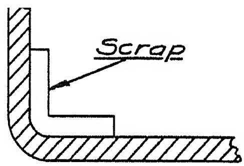


FIG. V

in a bend of this kind. If the strength of the flange is not of much importance, a satisfactory job can be done by adjusting the jaw so that there is a slightly greater distance from point "b" to surface "e". However, if it is desired to make a good true radius inside the bend, the jaw should be adjusted so that the distance from "e" to "b" is twice the thickness of the metal, or, in the case above, 1/8". By placing a piece of scrap material of the same thickness over the bend line, a bend such as illustrated by the shaded portion of Fig. V will result. If scratches are to be avoided the metal should be protected by sheets of wrapping paper on both sides and the surface "a" should have a light coating of machine oil. The radii given in the table on page 117 should be used when bending aluminum alloy.

FORMING SHEET METAL

In aircraft work, the expression "forming metal" usually means shaping or bending metal in two dimensions. This is a more difficult operation than bending in one dimension, for some portion of the metal must be stretched or shrunk. A simple explanation of this is in the curving of an angle flange. For example, if a strip of metal 2" wide is placed in a brake and bent along its length to a 90° angle, a straight angle-piece with 1" flanges will be formed.

SHAPING SHEET METAL
(continued)

This angle-strip will resist bending in any direction except along the axis of the first bend. However, if one flange of the strip is placed over a metal block and hammered, the metal in this flange will be stretched. When the metal is stretched it will occupy a larger area. In the case of the angle-strip, this increased area, or spreading, of one flange causes the other flange to curve, as illustrated in Fig. VI. Likewise, it will be seen that the line "a", due to the stretching of the metal, has become longer than the line "b".

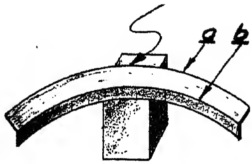
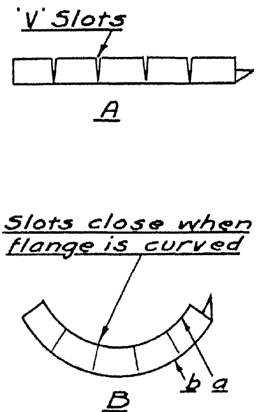


FIG. VI

To curve an angle-strip in the opposite direction would involve shrinking the metal in one flange. The theory of this can be clearly understood by sawing several small V slots in one flange of the angle-strip and then bending, as shown in Fig. VII-A. As the bend is made the V slots will close until they butt, as shown in Fig. VII-B. Line "a" will be shorter than line "b", for it has a smaller radius.



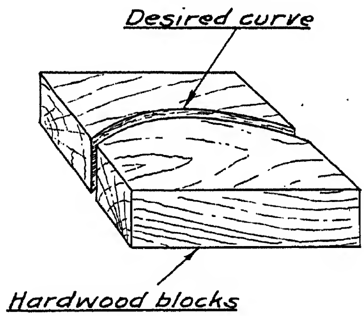


FIG. VIII

It is more difficult to make an angle strip with inside curve as in Fig. VII, without cutting V slots, especially if the material is very hard or heavy. However, if suitable preparations are made it can be done. First a bending mandrel must be prepared which has one surface shaped to the desired curve. Some means must be provided to clamp one flange to the curved block. One of the simplest methods of preparing bending blocks is to cut them from hard wood. Two blocks such as shown in Fig. VIII are suitable for bending an inside curve on an angle strip, and may be prepared quickly with the aid of a band saw. Of course if many pieces are to be curved the

SHAPING SHEET METAL
(continued)

block should be of some harder material.

To make the curved angle-strip the flat material is placed between the blocks so that the bend line is level with the top surfaces of the blocks. The inside corner of the convex block can be rounded to give the bend any radius desired. After the material is in place the blocks are securely clamped so that the material is held firmly. The bend is made by hammering the extended portion down evenly with a wood or rawhide mallet. No difficulties should be encountered if the material being bent is soft aluminum, aluminum alloy, or copper. Harder materials may start to buckle as the angle of the bend increases. If this happens the buckled portion should be straightened by inserting a screwdriver between the metal and the block and prying up the flange. Next, remove the metal and re-anneal it, for it may have become hardened by the hammering.

After the material has been re-annealed and replaced in the blocks, the bending of the flange can be continued. On very hard metal, such as steel, it may be necessary to stretch the flange near the bend as well as to shrink the outside of the flange. To better understand the action which takes place when this is done, consider the material being bent as a sheet of rubber. If the rubber were clamped between the blocks the extended portion could be bent down to 90° very readily, however, there would be several folds in the bent portion. But if the rubber were bent down and then stretched, or pulled away from the bend, a smooth flange would result. Of course, if the rubber were stretched it would get thinner and that is exactly what happens to the metal. For this reason the metal should be stretched as little as possible.

After the bend has been completed, any excess material which may extend beyond the desired flange length may be removed and, depending on the material and finish desired, all small bumps and dents removed with a file, steel wool, or emery cloth.

BENDING FLANGES ON CURVED SHEETS

Very frequently it is necessary to bend a flange on a sheet of metal that has curved edges, such as a round or elliptical tank end, curved sections of cowling, etc. Fortunately, the material used is usually some form of aluminum alloy which is either soft enough or can be annealed until it is soft enough to be stretched or shrunk readily. A short flange can be bent on a curve of large radius by simply placing the material on a flat bench so that the portion to be bent extends over

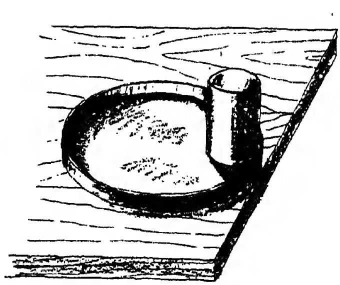


FIG. I

SHAPING SHEET METAL
(continued)

the edge. A heavy metal or a hard wood block, one side of which approximates the desired curve, is placed directly above the bend line as shown in Fig. I. The bend is made by hammering the extended portion of the sheet upward with a wood or rawhide mallet. Care should be taken to hold the bending block firmly on the sheet so that the metal in the sheet will not buckle.

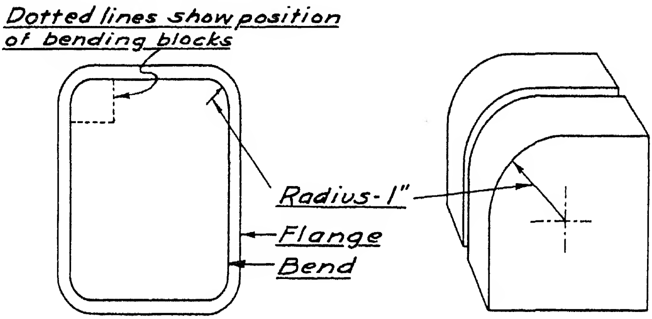


FIG. II

If a large flange is to be bent, or if the sheet is curved to a small radius, the above method will not be satisfactory. The procedure to be employed is simply a reversal of the method used for bending a curved angle strip, which has been described previously. Two bending blocks should be prepared from hard wood, each of which has a flat surface to be placed next to the sheet and has edges which are curved to correspond to the flange curve desired. For example, if it were desired to bend a 3/8" flange around the edge of the sheet shown in Fig. II-A, two hard wood bending blocks (Fig. II-B) should be prepared so that the curve of the edge of the blocks matches the curve of the bend line exactly. In this case the edges of the blocks would form a 1" radius.

Inasmuch as the flanges on the sides of the sheet are straight, the first step would be to bend all four flanges in a brake. Next, place one of the bending blocks on each side of the corner bend line and clamp them together securely. A little improvising may have to be done in order to clamp these blocks together. However, if the sheet is not too large,

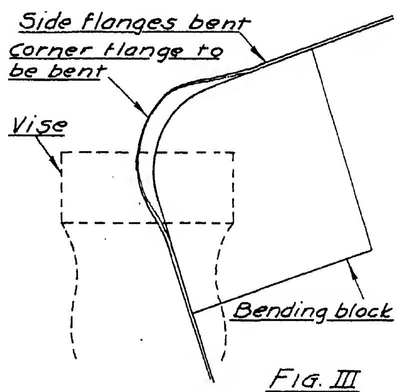


FIG. III

SHAPING SHEET METAL
(continued)

the clamping may be accomplished by placing them between vise jaws, as shown in Fig. III. If this method is not practicable, two large wood parallel clamps can be used for the purpose. Before starting the bend, a screwdriver, or other flat-ended tool, should be forced under that portion of the curved flange which was bent on the brake. By prying upward, this portion may be straightened so that the entire bend can proceed evenly. The bend is made by hammering the flange down onto the block. If the material is very soft, a wood or rawhide mallet may be used. If the material is hard, a steel hammer may be required to make the bend. Care should be taken not to allow the flange to buckle at any point. If a buckle does appear, a screwdriver should be used to pry the buckle out while the hammer is used to straighten the flange.

It may be necessary to re-anneal the material before the flange can be completed. If, after the material has been re-annealed, it still does not bend without buckling it will have to be stretched around the curve. As it is desirable to stretch the material nearest the bend, the metal should be hammered with a steel hammer in this area. By forcing the metal near the bend down onto the bending block and gradually working outward, the material will be stretched smoothly over the curve. After the bend is completed the flange height should be scribed around the curved portion so that any excess material may be cut off with a pair of tinsnips. The finished flange may be smoothed with a file or emery cloth.

To bend a flange on an elliptical sheet it may be necessary to make the bending blocks large enough to cover at least one-half of the sheet, and, if practical, it is better to make them the full size of the sheet. If many identical flanges are to be made, the blocks should be made of metal.

BUMPING METAL

"Bumping" is the term applied to shaping, or forming, metal by hammering. It is done wherever it is necessary to bend or shape sheet metal that has a double curve such as in engine rings, engine cowl, fillets, strut ends, etc. Bumping can only be done on malleable metals, that is, metals that are capable of being extended by hammering or rolling.

Bumping is accomplished by extending or stretching the metal by hammering. As can readily be seen, the metal must be supported on one side so that the hammer blows will flatten the metal and not simply dent it. The material is usually supported or backed up with a smooth surfaced iron block called a "dolly block." As the shape of the desired product varies greatly, many types, sizes and shapes of dolly blocks are used. The hammer used is usually of light weight with a rounded polished face. Here again special conditions call for special shape hammers. A few of the various types of dolly blocks, files, spoons, hammers, etc., used in bumping metal are shown in Fig. I.

The dolly blocks and hammers shown in Fig. I are also widely used in straightening and removing dents from damaged cowling.

SHAPING SHEET METAL
(continued)

For shaping or smoothing small objects, the material is often backed up with a closely-sewed, soft leather bag filled with sand, Fig. II. The sand bag can be shaped to fit the material being worked, and will change its shape to correspond with the changing shape of the metal as it is hammered. A satisfactory sand bag can be made using canvas in place of soft leather.

Fig. I

If it is required to make a number of similar pieces, or for bumping out objects that require considerable stretching, a bumping mold is used. Concave molds are usually used and the material is stretched into the mold by hammering. Molds can be made of several materials, the most popular of which are hardwood and lead. Hardwood is inexpensive and can be cut to shape with wood tools. Lead is more expensive, but can be remelted and recase into a new shape any number of times. In hammering metal into a mold, the work should be started close to the edges and the material gradually worked into the concave. Care should be exercised to avoid working inward too rapidly or the metal will not have sufficient support and the hammer blows will tear instead of flatten the material.

In replacing a large section of damaged cowl of special shape, such as the nose cowl for a water-cooled engine etc., a good method is to hammer the damaged cowl back into the original shape and rivet in some stiffeners to hold it in that shape if necessary. Fill a suitable size box with mixed cement and just before the cement hardens, press the original cowl into the cement. After the cement has hardened enough to hold its shape, remove the cowl and smooth out any irregularities or dents. This will make a good mold, to which the new cowl may be fitted.

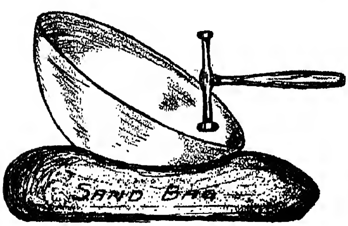


FIG. II

Bumped cowling should be smoothed to remove all traces of tool marks.

SHAPING SHEET METAL
(continued)

This is done with the aid of a coarse "body" file. This file has one course of curved teeth grooves as shown in Fig. I. The body file is used, as it readily cuts soft metal without choking or filling up the gullets as quickly as the conventional type file. After all tool marks and high spots are removed, the cowl is then polished, using emery cloth and steel wool. If a higher polish is desired, the material can be buffed with an electric buffer.

Pneumatic and mechanically driven hammers are used in factories to shape large sections such as engine rings and nacelle cowls. The methods and principles are the same as for hand bumping, the difference being in the tools used.

STAMPING AND PRESSING SHEET METAL

Forming sheet metal parts by forcing the flat metal into molds or dies is called stamping, or pressing. In the broader sense there is no difference in meaning between the two terms. However, the term "stamping" is generally understood to mean the forming of small objects which can be shaped by one rapid blow of a machine, whereas "pressing" is applied to the process that utilizes a slow, steady stroke or blow to form a large section. The machinery used for these processes includes hydraulic, mechanical, and manually operated presses and drop hammers. Various sizes of machines are used and it is not unusual to see a factory equipped with presses of over 1,000 ton capacity.

Fabrication of parts by stamping and pressing brings the aviation industry one step nearer to mass production. However, constant changes in aircraft design make it necessary to alter or replace the dies frequently. For this reason it is desirable, where possible, to avoid the use of steel dies. Steel dies give long service but there is considerably expense involved in their manufacture. Fortunately, the material from which most parts are stamped is relatively soft, permitting the use of dies made from materials more easily shaped than steel.

One material which has proved successful in the construction of forming dies is laminated hardwood. Such woods as birch and maple can be laminated to make as large a block as desired. The wood block, or blank, can be given a suitable shape with woodworking tools. One die is given the concave form and is called the female die. The male die is convex and shaped to match the female die exactly, allowing for the thickness of the metal to be formed. Although the blanks from which the dies are made are comparatively inexpensive, the actual construction of the die requires a high degree of woodworking skill, consequently a good diemaker can command high wages.

Hardwood dies are not, as a rule, as successful on drop hammers as on presses. The sudden impact of the drop hammer tends to deform the dies. Hence, many manufacturers use lead-and-zinc dies in this machine. The first step in constructing lead-zinc dies is to build a female die of plaster. The plaster die is then used to make a mold. This mold is usually made by packing the plaster pattern in molder's sand. When the pattern is removed, molten zinc is poured

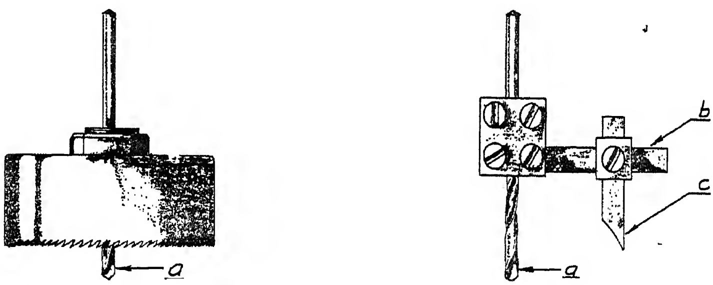
SHAPING SHEET METAL
(continued)

into the mold, forming a female die. The female zinc die is placed in a container and molten lead poured onto the zinc, thus forming the male die of lead. Iron bolts may be placed in the lead die before the lead has solidified to provide means for attaching the die to the hammer. Ordinarily, the zinc die is clamped to the base of the hammer and the lead die to the drop. This combination has proved very successful for the lead die is soft enough to give slightly under the force of the impact, thereby exerting equal pressure on all parts of the material being formed. The lead die will retain its shape for a considerably length of time for at each impact it is hammered against the hard zinc die, thus reshaping the lead to its original form.

CUTTING AND FLANGING HOLES

Cutting - There are several methods of cutting holes in sheet metal. If the metal is not too hard the holes may be punched, using a punch with a square or concave end and supporting the metal on a block of lead or the end grain of hard wood. This procedure is not recommended for use on any structure when accuracy or strength is paramount.

Large round holes may be accurately cut by using either a circular metal cutter or a fly cutter, Fig. I. The circular cutter



B

(I-A) consists of a small diameter metal twist drill (a) which serves as a guide and also as a shaft to support the cup-shaped cutter. Various sizes of cutters are provided so that different diameter holes may be cut. The fly cutter also has a small twist drill (a), serving as a guide and shaft. A cross arm (b) is fastened to the drill. A cutter (c), similar to the tool bit on a lathe, is attached to the cross arm. The position of the cutter can be changed to give a hole of any diameter desired, within the limit of the adjustment. The procedure in cutting a hole with either of these tools is the same. The cutter is held in a hand or bench drill and the guide drill (a) started in a center-punched location point. The material should be supported or backed by a smooth wood block. After the pilot hole

SHAPING SHEET METAL
(continued)

has been drilled the circumference cutter is brought in contact with the metal. Continued drilling cuts the large hole. Care should be taken not to turn the drill too fast or to use too much pressure, as the metal is likely to be stretched or the tool damaged.

Oval or irregularly shaped holes may be cut by drilling a starting hole and cutting along the scribed line with a coping saw equipped with a metal cutting or jeweler's saw blade. Also, where such equipment is available, a high speed metal router or a nibbler may be used. A small hand nibbler which is highly successful for cutting thin gage material is illustrated in Fig. II. A one-inch starting hole is cut to allow the lower jaw of the nibbler to be inserted. When the tool is operated a series of small overlapping holes are punched which form a continuous cut.

Courtesy BUCKEYE PORTABLE TOOL CO.

Fig. II
Pneumatic Nibbler

Flanging - Flanges can be made on circular holes by placing the material over the open end of a tube or pipe and hammering a flange on the material with the round end of a ball peen hammer. The inside diameter of the pipe should be equal to the diameter of the hole plus 2 times the flange width. If this method is used great care should be taken to see that the material is centered over the pipe opening and that it does not slip during the hammering, as otherwise the flange will be wider on one side than the other.

A much better method for flanging holes is to make a male and female die as shown in Fig. III. For soft material the dies can be made from hardwood. The guide (a) should be the same diameter as that of the hole to be flanged and should be long enough to extend through the material and fit the matching hole in the female die (c). The shoulder (b) should be as wide as the flange desired and at the same angle. The bevel (d) is cut to match the shoulder (b). Dies of this type can be quickly cut on a wood lathe. If a more permanent set of dies is required, they can be made of steel.

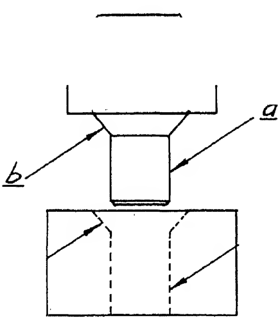


FIG. III

The procedure for making die-formed flanges if obvious. The material is placed over the female die. The male die is put through the hole in the material and entered into the matched hole (c). This automatically centers the material over the die. The flange is made by simply hammering on the top die to force the flange to assume the shape of the shoulder (b). The process is improved somewhat if a coating of light oil is placed on the shoulder of the die.

MACHINES

Rotary machines such as those illustrated in Fig. I have a variety of uses wherever sheet metal is being formed. Power machines of this type are used in many factories but, in principle, their operation is similar to the hand-operated ones. Rotary machines are provided with several sets of interchangeable rollers, a few

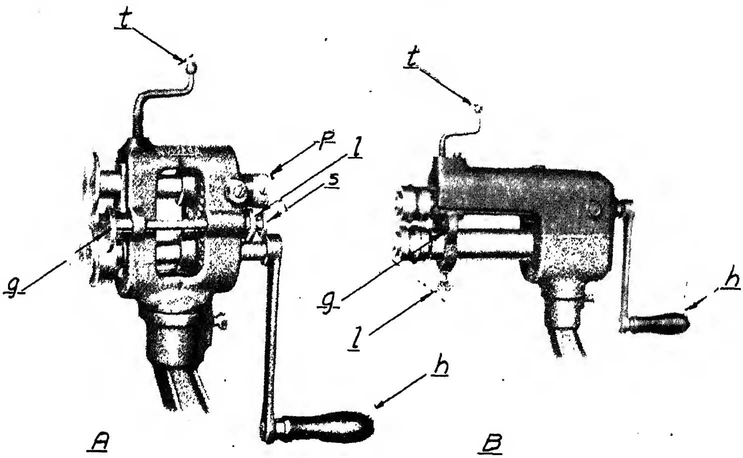
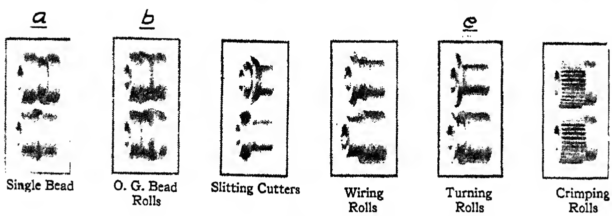


FIG. I ROTARY MACHINES

MACHINE and TOOL WORKS

ples of which are shown in Fig. II. These rollers can be used for beading, wiring, turning, slitting, etc. For special purposes rollers of other shapes are designed and fitted to the machine. The deep-throated rotary machine, shown in Fig. I-B, permits the rollers to be used farther from the edge of the sheet than would be possible with the type shown in Fig. I-A. Some of the operations which can be accomplished with the standard rollers are discussed below.



TYPES OF ROLLS

BEADING SHEET METAL

A simple bead, Fig. III, can be run in sheet metal by using the rollers illustrated in Fig. II-(a). There are several different methods of attaching rollers, one type of which is threaded on. In

ROTARY MACHINES
(continued)

such cases it is customary to make the bottom roller and shaft with left hand threads to prevent the roller from unscrewing when in use. The gage plate (g) should be adjusted by means of the screw (s) so that the distance from the face of the gage to the center line of the roller is the same as the distance from the edge of the sheet to the center line of the desired bead. After this adjustment has been made it is locked by tightening the nut (l).

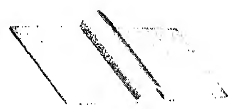


FIG. III BEAD

The bead is started by inserting the material between the rollers until its edge rests squarely on the face of the gage. The tension screw handle (t) should be tightened so that the top roller rests firmly on the material. When the handle (h) is turned, the rolls should pull the sheet forward and at the same time force a small depression into the metal. The first time the metal is run through the machine the tension on the top roller should be just sufficient to cause the roller to mark the metal. On subsequent rollings the tension is increased until the maximum bead is obtained. If an attempt is made to make a deep depression on the first rolling it will be extremely hard to make a true bead, for as the metal is depressed it is pulled away from the gage plate. When rolling beads in sheet metal a light coating of machine oil on the rollers will help prevent scratching of the metal. Although it is not ordinarily used, masking tape can be put around the rollers so that they will not mar soft material. Rollers such as shown in Fig. II-(b) can be used to form a double, or O.G., bead, as shown in Fig. IV.

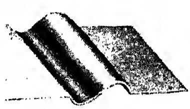


FIG. IV O.G.

It is not necessary to force or pull the material through the rollers, and only a slight pressure should be required to keep the sheet resting against the gage. If any difficulty is experienced at this point, the edge of the metal opposite the gage plate may be lifted slightly. This will aid in holding the sheet against the gage. Of course, as the bead is deepened the material will draw away from the gage, but by this time a sufficient "track" should be formed to keep the rollers and the metal aligned.

SLITTING

The roller combination shown in Fig. II-(c) can be used to make slits or cuts in sheet metal. The procedure is, in general, the same as that described above. Care should be taken not to attempt to slit metal which is heavier than the capacity of the machine.

MARKING BENDING FLANGES

Where it is desired to bend a flange on sheet metal, the bend can be started by using the roller combination shown in Fig. II-(d). To start the flange the same procedure is followed as was described above for beading.

ROTARY MACHINES
(continued)

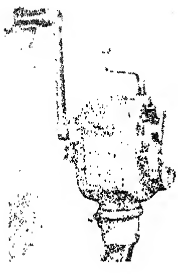
The horizontal position of the rollers must be adjusted so that the edge of the top roller extends beyond the flange in the lower roller for a distance greater than the thickness of the metal being rolled. The horizontal position of the top roller can be adjusted by the lock screw arrangement located at the rear of the top shaft shown in Fig. I-(p). Caution: Do not attempt to make a very large bend in this manner, for if too much tension is put on the top roller its sharp edge will cut the material. Another type of wiring rolls is shown in Fig. V.


Wiring Rolls

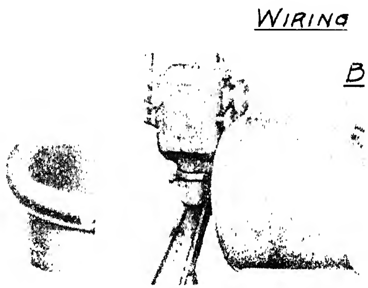
Fig. V

ROLLING WIRE EDGES

A hard wire is often rolled into the edge of a sheet of metal for the purpose of reinforcing, as shown in Fig. VII-A. A wire edge of this type can be made on the rotary machines by first turning a curved flange (Fig. VI) with the turning rolls shown in Fig. II-(e). After the flange has been turned the wire is placed in position and the flange rolled over the wire, as shown in Fig. VII. Rolls of the type shown in Fig. VIII are used for this purpose.


TURNING

. VI



Courtesy NIAGARA MACHINE & T

FIG. VII

The amount of material to be allowed for the wire edge depends, of course, on the size of wire being used. An allowance of 3 times the thickness of the wire is usually satisfactory. If an exact allowance is required, a short sample section should be prepared, as the material needed will vary with the material and method used. The larger the wire the easier it is to do the job; however, a small wire makes a neater appearance.

Where it is necessary to have a wire edge on metal that is bent to a small radius, less difficulty will be encountered in the fabrication if the wire can be rolled in the metal before the metal is bent.

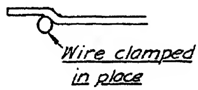

Burring Rolls

Fig. VIII

If rotary machines are not available a wire edge can

ROTARY MACHINES
(continued)

be made by bending an offset of the proper size, clamping the wire into the offset and then hammering the flange over the wire. A cross peen hammer should be used to complete the wire edge, as shown in Fig. IX.



CRIMPING

The edge of sheet material may be crimped, as shown in Fig. X, by using the crimping rolls shown at the first of this section, Fig. I-(f). The same procedure is used as in other types of rolling except the first run should be fairly heavy in order to make sure that subsequent runs will follow n the same crimps.

The illustrations pertaining to rotary machines were furnished through the courtesy of the Niagara Machine & Tool Works, who furnish many metal forming machines for the aviation industry.

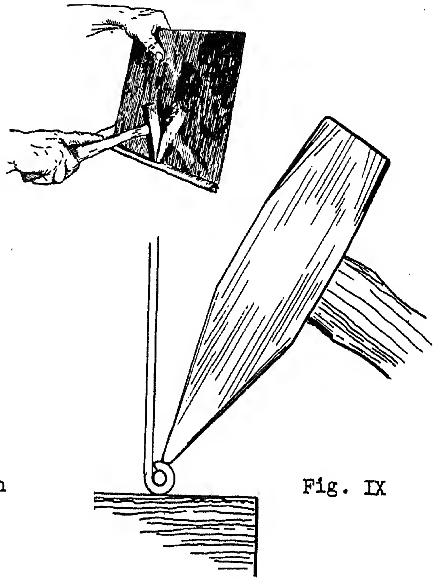


Fig. IX

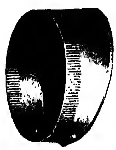


Fig. X

LOCK AND STANDING SEAMS

Lock seams, such as those shown in Fig. I, are used frequently in the construction of tanks and other containers. As the name implies, this seam is self-locking, but as a rule the seam is further reinforced by a few rivets if the material is aluminum alloy, or by soldering if it is of steel or copper. The lock seam, or groove seam as it is often called, is made by bending a flange of the desired size on each edge of the metals to be joined. The flange bend should be closed to approximately the degree shown in Fig. I-(a). At this point the two flanges are hooked together and flattened. A grooving tool, Fig. II, is used to force an offset in one sheet, thus locking the seam. The grooving tool must be of the correct

ROTARY MACHINES
(continued)

Preparation
(a)

Outside Seam
(b)

Inside Seam
(c)

Gage No.	16	18	20	22	24	26	28	30	32
A inches	15/32	7/16	11/32	19/64	1/4	13/64	3/16	11/64	1/8
B inches	5/8	9/16	7/16	3/8	5/16	1/4	7/32	3/16	5/32

Fig. I Lock Seams

size to fit the seam, for if it is too large the seam will spread open, and if it is too small the metal will be damaged. In an emergency a fairly satisfactory substitute for the grooving tool can be made by filing a groove in a hardwood block.

If the lock seam is used for the closing seam or in any other place where the overall dimension, including the seam, must be accurate, the proper allowance must be made for the seam. A practical allowance would be 3 times the flange depth, plus 3 times the thickness of the metal, plus approximately 1/16" (for thicknesses up to 1/8"). If a more exact allowance is needed, sample seams should be prepared to ascertain the exact requirements. Note: Sample seams should be made by measuring the overall dimensions of two sheets before the seam is made. After the seam is completed the overall length should again be measured to find the exact allowance required. The chart in Fig. I shows the recommended seam sizes for various gages of metal. Other sizes may, of course, be used but these have been found to give the maximum strength for the minimum of material.

On straight runs the lock seam flanges may be bent either in a brake (see Bending Flanges) or in a bar folder such as shown in Fig. III. Machines of this type are very

Fig. II

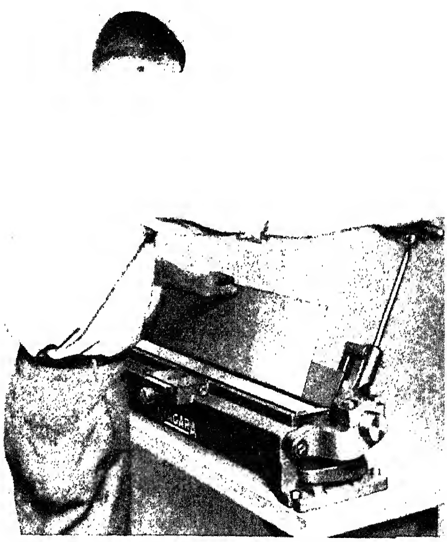


Fig. III Niagara Bar Folder

ROTARY MACHINES
(continued)

convenient for flanging small pieces of metal. The flat material is slipped into the machine from the side opposite the operator and rests on the bending leaf, or wing. The material fits between the jaw and the folding blade with its edge against the gage. The width of the flange is determined by a readily accessible gage adjustment located directly in front of the operator. The material should be held firmly against the gage until the handle is raised slightly, causing a cam arrangement to clamp it firmly between the jaw and the folding blade. Further movement of the handle bends the material. Bends of about 175° can be made on this machine. An adjustment in the rear of the folder allows the cam roller to be raised or lowered, adapting the clamping action to various thicknesses of metal.

The table, or wing, may be lowered to produce a rounded flange, such as used when making wire edges. Stops are provided to regulate the degree of bend, as desired.

The standing seam, shown in Fig. IV, is used largely for corner seams such as those that might be found between the head and sides of a tank. It is formed by bending flanges, as in Fig. IV, and then closing the flanges, as in IV-(b). A "setting down" machine, such as that shown here, may be used for the latter operation. If desired the completed seam can be bent as in (c) to increase the tightness of the joint.

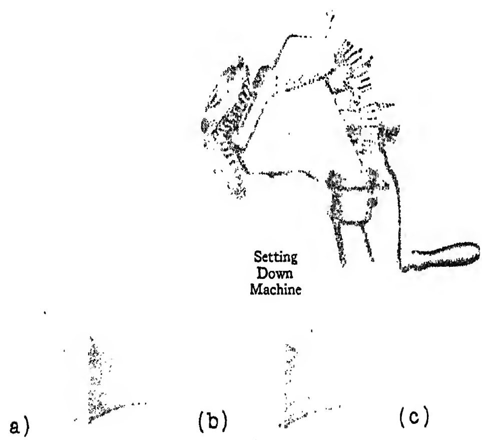


Fig. IV

HOW TO MAKE AN INSPECTION COVER

An inspection plate designed to be fastened to a wood frame in the model wing section, can be built with little material and the use of only a few tools. By making this inspection cover and plate, some idea will be had of the construction and use of inspection covers.

MATERIAL: Two pieces of .035" aluminum, 8" x 10"; one piece of 3/32" pyralin, 6" x 8"; one dozen #6 binder head aluminum rivets; round head wood screws, #6 x 3/4"; one cowling stud; one cowling pin; 1/8" x 3/4" strap iron.

TOOLS: Steel scale, square, tin snips, ball pein hammer, rivet set, files, screw driver, drill.

PROCEDURE:

1. Cut a base for the cover by squaring one piece of aluminum to 6" x 8".

2. Cut out the inside of the base, leaving a 3/4" frame, Fig. I. Refer to sheet on "Tin Snips".

3. Finish the base by filing away all burrs and giving a small radius to all corners.

4. Make the second frame identical to the first, except one is cut out straight as shown by the dotted lines on Fig. I.

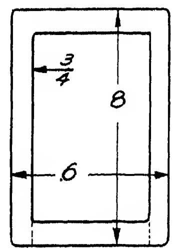


FIG. I

5. Mark a 1/4" line around the outside edges of the frame.

6. From the 1/4" line, bend a 1/8" offset in both sides and the end of the frame to allow the pyralin plate to be slipped between the frame and the base.

Note: This may be done by clamping the frame and the base between two steel bars held in the vise, as shown in Fig. II. One steel bar should support the entire width of the base frame, while the other should be even with the 1/4" line on the outside frame. Pry the outside frame outward to permit the 1/8" iron strap to be placed between the frame and the base. Hammer the frame back straight over the strap. This should be repeated on the end and the other side. This will give an offset in the frame, as shown in Fig. III.

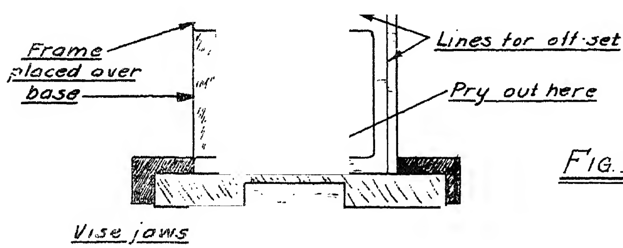


FIG. II

HOW TO MAKE AN INSPECTION COVER
(continued)

7. The frame and base can be held together with two or three #6 rivets on each side.

8. The pyralin should be fitted to slide into the frame, or to a size of approximately 5-1/4" x 7-1/2".

Slide the pyralin into place and drill a small hole through the pyralin and through the base in the middle of the base frame, at the open end. See Fig. III.

10. Remove the pyralin and place a cowling stud (Fig. IV) in the hole drilled in the frame.

11. Enlarge the hole in the pyralin to fit over the cowling stud.

12. The entire frame should be gone over with a smooth file to remove any possible burrs, and should be polished with emery cloth.

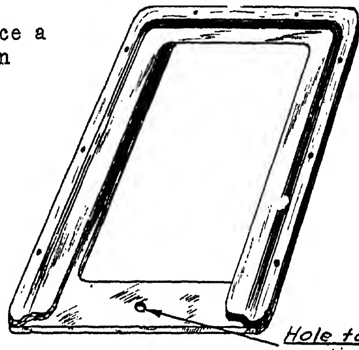


FIG. III

After the fabric has been put on and doped, the inspection frame can be screwed to the previously made framework. The frame should be put on so that the open end is toward the trailing edge of the wing. The fabric is then cut from the inside of the frame, leaving enough excess fabric to allow it to be folded back and tacked to the under side of the framework. This prevents the fabric from pulling away from the inspection plate.

The pyralin plate can now be slid into place, hooked over the stud and secured with a cowling pin, Fig. V.

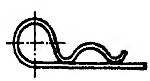


FIG. V

Cowling pin

Cowling Stud

SHEET METAL FASTENINGS

There are three main types of fastenings used in making semi-permanent or permanent joints in sheet metal: Machine screws, Parker-Kalon self-tapping screws and rivets. This does not include, of course, the various types of cowl fasteners which are discussed under "Cowl Fastenings", nor wood screws which may be used in attaching sheet metal to wood.

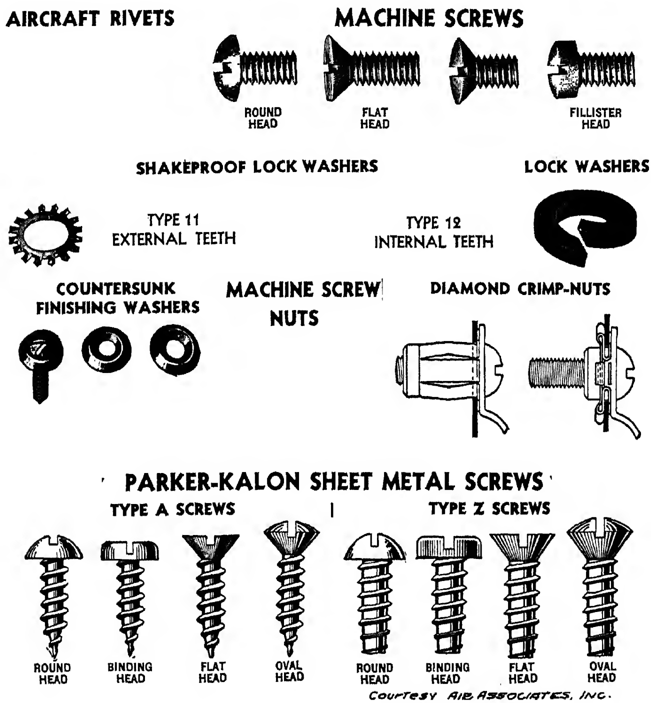


Fig. I

Fig. I shows the three kinds of fastenings. The rivet is the round head type which is by far the most common. Other types of rivets with dimensions of the heads are shown below.

MACHINE SCREWS. These may be obtained in the following materials: steel, plain or cadmium plated; brass, plain or nickel plated; duralumin; stainless steel.

COMMERCIAL MACHINE SCREWS

Mach. Screw No.	2	3	4	6	8	10	12	14
Threads per Inch	56	48	36	32	32	30	24	20
Diameter *	.086	.099	.112	.138	.164	.190	.216	.242

Thousandths of an inch.

SHEET METAL FASTENINGS
(continued)

Lengths run ordinarily from 1/4" to 3", depending somewhat on the size. That is, a No. 2-56 more than an inch long would be hard to find.

Machine screws should never be used to transmit stresses. Since they are threaded for their full length their bearing against the hole is poor. Furthermore, their strength is low. Their function in aircraft is simply to hold two pieces together yet permit removal if necessary. If quick removal is necessary, cowl fasteners are used. If the joint is permanent or transmits load from one piece to the other, rivets are the proper fastener. Lock washers should always be used under machine screw nuts and if the metal being joined is aluminum or dural, a plain washer should be placed next to the aluminum and under the lock washer to prevent chewing up the aluminum. A more finished job may be obtained on external work if oval head screws are used with the countersunk finishing washers illustrated. Whenever possible the nut should be tightened with a wrench and the screw driver slot used only to keep the screw from turning, but when it is necessary to use machine screws in a location which makes it impossible to reach the nut, the crimp nut shown is an invaluable aid. A hole is made in the under piece large enough to receive the crimp nut. As the screw is tightened the crimp nut squeezes down and becomes a permanent part of the under piece. When using this device, a lock washer should be placed under the head of the screw.

PARKER-KALON SCREWS. These are self-tapping screws which may be obtained with screw driver slots in the heads, as shown, or with out slots, in which case they are driven in and make their thread as they go. The latter type is not ordinarily used for fastening pieces of sheet metal to each other, but provides an extremely desirable method of plugging holes in tubes which have been drilled for oiling, or for any other place where they do not have to be taken out later. Parker-Kalon screws are ordinarily made of hardened steel, cadmium-plated, but are also manufactured of stainless steel where high resistance to corrosion is necessary. They save a great deal of time in assembly as no tapping is needed and no nut. In thin sheet metal they should not be used if they are likely to be frequently removed, as the thread will wear out after a time, but for semi-permanent attachments they are highly satisfactory. In drilling holes for their installation, the drill size should not be larger than the shank, and, in thin metal especially, if it is a few thousandths smaller, a tighter job will result. The type A screws are for joining sheet metal up to .050" thick (18 ga.), and the type Z for heavier metal up to 3/16" thick. In thick metal, especially, the screw driver should fit the slot accurately, as otherwise the slot may be ruined and the screw be made incapable of being driven. This, of course, applies to any screw, whether Parker-Kalon or not, as stated elsewhere in book.

RIVETS. Before the advent of welding in aircraft construction rivets were widely used for attaching pieces of sheet metal together, whether the material was steel, brass, aluminum, or any other metal. Steel rivets are still occasionally used where welding

SHEET METAL FASTENINGS
(continued)

for one reason or another, is not desirable, and copper rivets are found in rare instances in the construction of brass or terneplate tanks, but fully ninety-eight per cent of the riveting now done on airplanes is for the purpose of making joints in duralimin or aluminum, and the rivets are of corresponding material. Both duralumin and aluminum can be welded, but welding destroys some of the strength and resistance to corrosion of the former unless subsequent heat treatment is possible, and in the case of such structures as seaplane floats and boat hulls this is obviously impractical. Aluminum welds very easily but there are many places where riveting is more satisfactory. (Incidentally, the term duralumin has become a colloquialism and is no longer accepted technically. However, it is used in the trade and makes a convenient distinction between commercially pure aluminum and aluminum alloys, as explained further in the sheets on "Properties of Metals."

The strength of a riveted joint depends upon six factors: 1) the diameter of the rivets, (2) the number of rivets, (3) the strength, in shear and bearing, of the material from which the rivet is made, (4) the strength in bearing of the material being joined, (5) the thickness of the material being joined, (6) the number of planes along which shear is resisted. This list does not include such items as improperly headed rivets, holes too large for rivets, etc., but assumes that the workmanship is satisfactory and that the diameter of the hole is not more than 5% greater than the diameter of the rivet.

The diameter of the rivet needs no explanation only some designers use the diameter of the hole in calculating the strength instead of the nominal diameter of the rivet, since the rivet is considered as filling up the hole when it is headed. It is more conservative to use the nominal rivet diameter, however. The shearing strength of a rivet is its area in square inches times the shearing value of the material. The area is, of course, πr^2 or $.7854D^2$ = ($.7854 = \pi/4$). Example: Find the strength in shear of a rivet 1/4" diameter when the shearing strength of the material is 30,000 lbs. per sq. in. $.25^2 \times .7854 \times 30{,}000 = 1473$ lbs. The strength of material in shear is usually from 60% to 65% of its ultimate tensile strength.

A rivet may be amply strong in shear yet if the sheet through which it passes is too thin, either the sheet or the rivet (depending on which material has the lower bearing value) may fail in bearing, which means that either the edge of the hole will crumple or the sheet will cut into the rivet. The bearing value of material is usually 1.75 to 1.80 times the ultimate tensile strength of the material. The bearing strength of a rivet is the diameter times the thickness of the sheet times the bearing value of the material. Example: Find the bearing strength of a 1/4" rivet in sheet 1/8" thick if the bearing value of the material is 80,000 lbs. per sq. in. 1/4 x 1/8 x 80,000 = 2500 lbs.

This brings us to the interesting matter of designing the joint so that the strength of the rivets will be the same in both shear

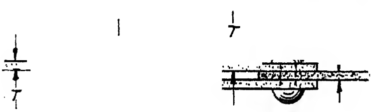
SHEET METAL FASTENINGS
(continued)

and bearing. Since, if the sheet thickness is not changed, the strength in shear increases in proportion to the square of the diameter and the strength in bearing increases only in proportion to the diameter, resistance to shear may be rapidly increased by increasing the diameter of the rivets instead of the number, whereas, if it is desired to increase the strength of the joint in bearing, the number of rivets should be increased. This may easily be demonstrated by using the two examples already given. If four 1/4" rivets are used, the bearing strength of the rivets will be 4 x 1473 = 5892 lbs. On the other hand, if one rivet 1" in diameter is substituted, the strength in bearing is still 10,000 lbs. but the shear strength is 1^2 x .7854 x 30,000 = 23,562 lbs. If two 1/2" diameter rivets were used, the bearing strength would remain unchanged at 10,000 lbs. but the shear strength would be 2($.5^2$ x .7854 x 30,000) = 11,781 lbs. Accordingly, to make the joint approximately uniform in strength, two 1/2" rivets would be the proper combination.

Another point to be considered in developing full bearing strength is the distance of the rivet from the edge of the plate. The Aluminum Company of America has demonstrated by test that this distance should be not less than twice the diameter of the rivet, measured from the center of the hole.

Item (6) in the list of factors may require further explanation also. Fig. II shows a single rivet in single, double and quadruple shear. The rivet in B will carry twice as much load as in A, and C will carry four times as much as in A. The center sheet in B, however, will carry no more than one of the sheets in A, and assuming that the joint A has been designed so that the strength of the sheet and the rivet are the same, to double the strength of the joint the thickness of the inside sheet(s) should be increased, as shown in Fig. III. "T" is a given thickness.

The "dimple" type of joint is made by using a punch and die to form the sheets and affords a means of countersinking rivets in thin material. If carefully done, its strength is somewhat higher than the standard joint. However, it is not recommended unless the proper tools are available.



B-Double Shear C-Quadruple Shear

Fig. II

show
on of forces

B-Double Shear C-Quadruple Shear Joint

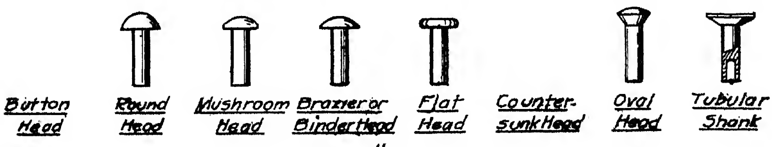
SHEET METAL FASTENINGS
(continued)

The reason that the dimple rivet (frequently called "flush" rivet) produces a stronger joint than the conventional round or flat head rivet will appear from a study of Fig. III. It will be noted that in order for the joint to fail in shear, not only the rivet, but also a section of the sheet must be sheared. On high speed airplanes and on the bottoms of flying boats, rivet heads offer an appreciable amount of resistance - air resistance in the first and water resistance in the second. Hence, dimple rivets, which offer no resistance to air or water are becoming increasingly common.

Before leaving the subject of rivet strengths, two more points should be considered. If the diameter of the rivet is large compared to the thickness of the sheet, the force required to head it often causes the sheet to bulge. For this reason, it is advisable to use rivets with a diameter of not more than three times the thickness of the sheet. On the other hand, small holes in thick sheets usually cause fabrication troubles. Hence, it is well to have the rivet diameter not less than the sheet thickness.

In the spacing of rivets, care should be taken that the sheet is not cut away so much by rivet holes that it will not develop the necessary tensile strength. In general, the Aluminum Company recommends a minimum spacing between centers of not less than three times the diameter of the rivets nor more than twenty-four times the thickness of the sheet.

Various types of rivet heads are shown in Fig. IV. The tubular rivet is made with a number of different styles of head.



Aircraft rivets are most commonly made from 17S, A17S, or 24S alloy. These designations acquire a "T", of course, after heat treatment, as, for example, 17S-T. The 24S rivets are the strongest (44,000 lbs. per sq. in. in shear) but also the hardest to drive. They must be heat treated before using. The 17S rivets come next in strength (34,000 lbs./sq. in.) and must also be heat treated. The third type, A 17S, while not as strong as the others, (30,000 lbs./sq. in.) is usually strong enough when used in the heat treated condition (A17S-T). They may be purchased already heat treated and do not need further treatment. For this reason they are more economical than either of the other two.

Since the strengths of the three alloys are different, some means of readily distinguishing the rivets made from them is necessary. This is taken care of by the identification marking shown in Fig. V.

SHEET METAL FASTENINGS
(continued)

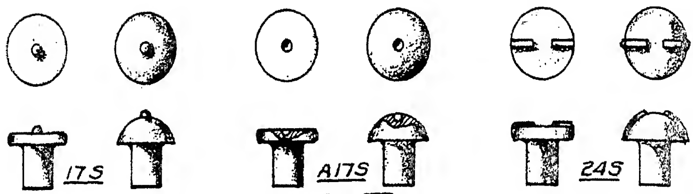


Fig. V

Obviously, every precaution should be taken to use the rivets specified on the drawing, since there is an appreciable difference in strength between the various types. In general, A17S-T rivets are used in such places as watertight joints in floats and hulls, gas tank seams and similar places where, in order to make the joint tight, more rivets are needed than are necessary merely for strength. Where it is essential that rivets be closer together (for tightness of the seam) than the three diameters specified above, two rows should be used with the rivet spacing staggered as in Fig. VI. Double tows may also be used to increase the strength of the joint.

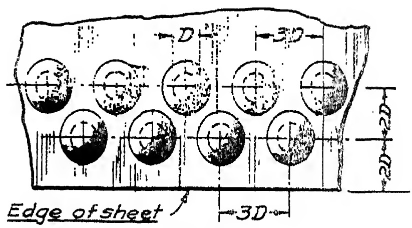


Fig. VI

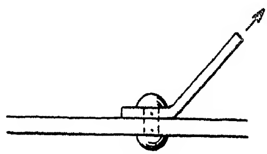
The heat treatment of 17S and 24S rivets is usually accomplished in a salt bath just as other aluminum alloy parts. In order to handle the rivets, they are usually put into a container of wire mesh or some other perforated receptable. Another practice occasionally followed is to use a large-diameter, thin walled tube, the lower end of the tube being sealed by a blank washer welded over it and the upper end extending above the surface of the salt bath. In this device the rivets do not actually come in contact with salt, but the tube must remain immersed in the bath long enough for all the rivets to become uniformly heated. The purpose of the salt in the bath is to make it easier to control the temperature.

Rivets made from 17S or A17S alloy should be brought to a temperature of 930° F. to 950° F. and held there until there is no doubt that all rivets in the batch, or "load", have become uniformly heated. They are then withdrawn from the bath and immediately quenched in cold water. In the case of 24S, the temperature should be from 910° F. to 930° F. The remainder of the procedure is the

SHEET METAL FASTENINGS
(continued)

As stated previously, A17S-T rivets may be driven in the heat treated condition and after aging has been completed. This is not the case with those made from 17S or 24S. Rivets of 17S (or, after heat treatment, 17S-T) should be driven within an hour after quenching, and 24S-T rivets even more quickly. However, by keeping them in a refrigerator at a temperature of 32° F., aging may be delayed twenty-four hours, and if they are kept on "dry ice", (solidified carbon dioxide, temperature -150° F.), as is common practice with most manufacturers, they will remain soft for an extended period of time. As soon as they are brought to room temperature, aging proceeds at the normal rate.

Rivets should never be subjected to tension loads such as illustrated in Fig. VII if it is possible to avoid it. The head of a rivet is not designed to resist the tendency to pull off, which such a condition imposes upon it. A little study of the illustration will make clear the prying action of the lug, which tends to bend the rivet and wrench off the head. If it is absolutely necessary to use rivets for such loads, the strength should be considered as not more than half the strength in single shear. Instructions as to the installation of rivets will be found on the following pages.



Poor Practice

FIG. VII

RIVETING

Probably the most common use of rivets in aircraft construction is the fastening of aluminum alloy sheets. As this type of fabrication is employed, at least to some extent, on practically every airplane built, the importance of the correct selection and the correct driving of rivets cannot be over-emphasized. Information concerning the various types of rivets and their uses will be found in the preceding section.

EQUIPMENT FOR HAND RIVETING

The tools which are required for hand riveting include drills, reamers, rivet cutters or nippers, bucking blocks, hammers, draw sets, and rivet sets. Other accessories which are often used when riveting are machine screws, clamps, patent fasteners and masking tape. As the proper selection of equipment is essential to good riveting, each of the tools above will be discussed briefly before starting riveting procedure.

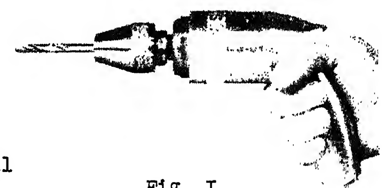


Fig. I
Buckeye Portable Tool Co. Drill

Drills - Standard twist drills are used to drill rivet holes. However, as much of the work is with aluminum alloy, the drill can be sharpened so that the cutting edge is flatter, or forms an angle greater than 59°. A drill which has a sharper point will cut faster in soft material, but for hand drilling a drill with a flatter point will, as a rule, leave fewer and smaller burrs. Locations for the rivet holes should be center punched and the actual drilling done with a light power drill. Fig. I shows one type of drill which is very satisfactory for light gage material. The drilling can be done with a hand drill if no power tool is available, but much time will be wasted. Also as the drill speed is slower when the work is done by hand, there is a tendency to apply more pressure, consequently a large burr is often formed as the drill pierces the material. All burrs must be removed before riveting.

Reamers - It is difficult to drill soft aluminum alloy without leaving a burr around the outside of the hole. These burrs can be removed quickly and easily by the use of a metal countersink. The countersink is merely inserted into the hole, given a few turns and the burrs are removed. Great care must be taken not to exert too much pressure on the countersink or the rivet hole will be tapered. A drill of a diameter larger than the rivet hole may be used in the same manner but there is an even greater danger of damaging the rivet hole, for very slight pressure will cause the cutting edge of the drill to remove more than the burr.

There are other ways of removing burrs from holes, such as by filing or by using a small bearing scraper or a three-cornered file which has been ground sharp near its point. The most effective method to be used on each particular job will be learned by experience.

RIVETING
(continued)

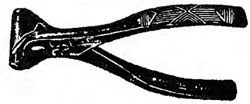
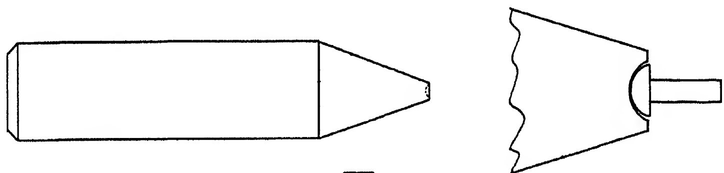


Fig. II

Rivet Cutters - When rivets of the proper length are not available, it is customary to use a longer rivet and cut it to the right length after insertion. Special end cutters or nippers, such as those shown in Fig. II, should be used for this purpose. These cutters have hardened steel jaws which are not easily damaged. Some have jaws which may be replaced when the original ones are no longer serviceable.

Buckir blocks - One of the essentials to a good riveting job is the solic bucking or backing of the rivet while the shank is being headed or "upset." The bucking block should be heavy enough to prevent any "bounce" when the rivet is hammered. Any large steel block will serve as a bucking iron provided it can be held squarely on the rivet. In many cases, obstructions close to the rivet make it necessary to use a specially shaped bucking iron. Considerable ingenuity may have to be used to devise an iron that can be used to buck rivets that are located in rather inaccessible places, but the main things to remember are that the iron should be heavy enough and so shaped that it may be held squarely on the rivet. Fig. III shows



. III

one type of bucking iron which can be used in many places. The shaft should be from 1" to 2" in diameter and from 8" to 12" long, depending upon the weight required. The tapered point permits it to be used where there are protruding parts or other obstructions close, to the rivet. The cup in the bucking iron should have a radius slightly larger than that of the rivet head, as shown in Fig. III. The oversize cup insures solid bucking of the rivet without danger of marring or scratching the material being riveted.

A bucking block may be used either to support the head of a rivet or to form the new head, depending upon the type of riveting being done (as explained on the following pages). If it is used to support the head, a cup or recess should be provided which will fit over the rivet head so that the head will not be deformed during the riveting process. A cup must be provided in the bucking iron when it is desired to shape the head of the rivet with the iron. This, of course, would not apply to flat head rivets.

Hammers - Cross and ball peen hammers, Fig. IV, are both used for hand riveting. The round end of the ball peen hammer can be used to form a round head on a rivet. In most cases a rivet set is

RIVETING
(continued)

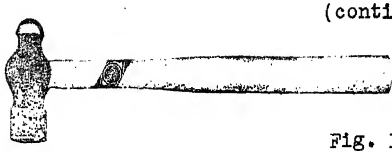


Fig. IV

used for this purpose for it is possible to obtain a much neater job. The square end of the cross peen hammer makes it adaptable for use in more confined spaces than is the ball peen. It can be used to form flat heads on rivets located in corners, near flanges, etc.

The weight of the hammer selected for the job should be considered seriously. One that is too heavy will cause the metal to be stretched excessively. A light hammer will cause the rivet to bounce when it is struck, thus tending to elongate the rivet hole or bend the rivet shank. It is hard to say just what size hammer should be used, because there are so many variables, size and material of rivet, type of head being formed, strength of blows, etc., but in general an 8 or 10 oz. hammer is satisfactory for driving 1/8" rivets.

Draw Sets - A draw set, Fig. V, is a tool similar to a flat-ended punch, having in the end a hole which is slightly larger in diameter than the rivet. The depth of this hole is usually 5 or 6 times its diameter. The draw set is used to force the rivet tightly into the rivet hole and to make sure that no space exists between the sheets of material being riveted.

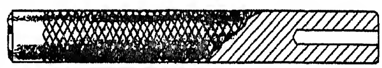


FIG V Draw Set

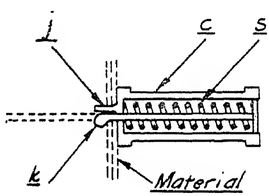
Rivet Sets - A rivet set is a punch-like tool provided with a cup shaped depression in one end. Various shapes of cups are used to fit or to form the various rivet heads. The end of the punch or set is hardened so that it will retain its shape in use. A rivet set of this kind can be made in the machine shop. The recess for the rivet head can be roughly cut to shape with a properly ground twist drill. Any rough or uneven spots in the recess can be smoothed by pressing or hammering a steel ball (from a bearing) into it. Care must be taken, however, that the ball bearing used is exactly the right size. Before the tool is used it should be hardened.

FIG. VI Rivet set

RIVETING
(continued)

Clamps and Fasteners - Sheets of metal to be riveted together must be held in position rigidly to prevent any slipping or creeping during the riveting process. Small iron "C" clamps can often be used for this purpose. Plywood or soft metal pads should be used under the clamp jaws to prevent damage to the material. Small wood parallel clamps can be used in many places for the same purpose.

When both pieces of material have been drilled, before the riveting is started a few machine screws should be used to fasten them together temporarily in order to prevent the holes from becoming misaligned through either the stretching or slipping of the material. Soft metal washers under the machine screw head and nut will forestall damage to the metal. On a long seam one screw should be sufficient for each foot.



A patented fastener, such as shown in Fig. VII can be used in place of a machine screw for temporary fastenings. Considerable time will be saved by their use, for not only is less time required for installation, but the work may be done from one side of the material. The clamp shown in Fig. VII consists of a plunger, held into a hollow cylinder c by means of a coil spring s. The end of the plunger rod is made in the form of a knob k. To use this clamp the plunger is pushed in so that the end of the plunger rod can be inserted through the rivet hole. The projection j on the end of the cylinder can now be inserted in the hole and, by releasing the plunger, the spring tension causes the knob to be drawn tightly against the inside sheet. Thus, the sheets of material are clamped firmly together. The plunger is operated by a special pair of pliers having a projection on one jaw and a slot on the opposite jaw which fits under the cylinder boss.

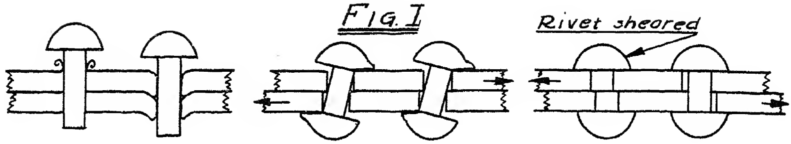
RIVETING PROCEDURE

After rivets of the proper type have been selected and their locations determined, the process of riveting starts with drilling the rivet holes. These should fit the rivets snugly and be free from all burrs. If the hole is too small the material will bulge when the rivet is driven, or the rivet itself will have a groove cut in its shank. If the rivet holes are too large the sheets may shift; also, rivets driven in holes which are too large are likely to bend in the shank. If some holes are too large and the others are the right size, the load is thrown entirely on the rivets in the latter, putting an undue shearing stress on these rivets, and possibly causing their failure, as in Fig. I.

Rivets must be of the correct length to be driven properly. If they are too long they will bend when headed, either in the shank or

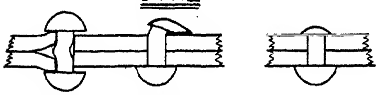
RIVETING
(continued)

FIG. I



the extended portion (Fig. II). A rivet which is too short will not form an adequate head. The proper length for the shank of a rivet is the sum of the thicknesses of the metals being riveted, plue one and one-half times the diameter of the rivet shank. For example, if two sheets of 1/16" metal are to be riveted with 1/8" rivets, the proper shank length would be 2 x 1/16", plus 3/16", a total of 5/16".

FIG. II



If a rivet of the correct shank length is not available, a longer one should be inserted in the hole and the extended portion of the shank cut to the proper length. In order to avoid any error when measuring the rivet shank for cutting, the rivet should be supported with a bucking iron, a draw set placed over the shank, after which a few blows of the hammer on the draw set will force the rivet tightly into place and eliminate any space between the sheets of material. Note: A small piece of masking tape placed in the cup of the bucking iron will prevent scarring of the rivet or material.

After the rivet has been properly set and cut to the proper length the heading, or upsetting, is started by striking the rivet a few blows with the flat surface of a steel hammer. The rivet must be firmly supported by the bucking iron during the entire riveting process. The first few blows should be comparatively soft to avoid bending the rivet shank. After the rivet has been swaged, or upset, sufficiently to prevent its falling out, the head may be completed by placing the cup-shaped depression of the set over the rivet and hammering the end of the set. (Fig. III) A neater job will be produced if the head of the set is rotated in a small circle as the heading proceeds. Considerable pressure will be required to hold the set firmly on the rivet and to prevent its bouncing. If the set is allowed to bounce, the head being formed will be damaged.

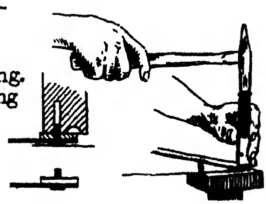


FIG. III

One of the most essential factors for a good riveting job is solidness of the bucking For this reason, where it can be avoided, a light bucking bar should never be used. Very

RIVETING
(continued)

often when rivets are replaced in floats, wing skins, etc., the person doing the bucking has to reach to almost impossible lengths through a small hand hole. In a position like this it is not always possible to use a heavy bucking iron, consequently when an attempt is made to head the rivet with a rivet set, the rivet is driven back through the hole. In such cases, the rivet should be headed by very light blows with the round end of a ball peen hammer, while the assistant bucks the rivet in the best manner possible. The rivet should never be struck a direct blow, but the head should be formed by tapping it around the edges. After the head is formed it can be smoothed by using the rivet set. If this method is employed great care should be taken not to allow the hammer to slip off the rivet and dent the material.

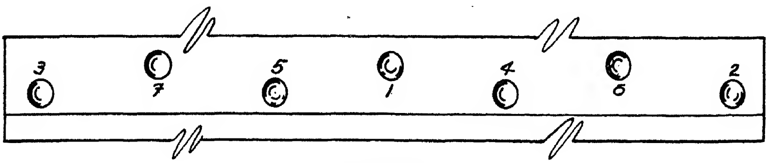


FIG. IV

Where a long line of rivets are to be driven, the sheets have a tendency to buckle due to a slight stretching of the material as the rivets are driven. The effects of this can be overcome by driving the rivets in the sequence shown in Fig. IV. This does not stop the material from stretching, but it does prevent the excess material from bulging at one point.

Sheets of metal are sometimes riveted to wood or other comparatively soft material. If the rivet shank must pass through the soft material, the hole should be slightly undersize so that the shank will be well supported. The shank should not be allowed to extend over 1-1/3 times its diameter, as there is a great tendency for the rivet to bend. Shortening the projecting shank lessens this tendency and, as a rule, a full head can be formed because the soft material through which the shank passes will be slightly compressed.

TYPES OF RIVET HEADS

There are several shapes of head that may be used when heading rivets. In a repair job the correct type will be determined by an inspection of the shape of the original heads. If new work is being done in which there are no specifications for the riveting, the type of head chosen will depend largely upon the appearance desired. The most easily formed shape is the flat head, illustrated in Fig. I-A.

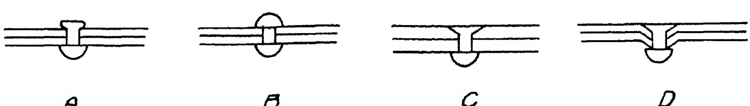


FIG. I

RIVETING
(continued)

This head may be formed by supporting the rivet with a cupped bucking iron and flattening the head with a hammer. It may also be formed by placing a flat bucking iron on the end of the shank and hammering the headed end of the rivet with a rivet set or pneumatic gun. Rivets formed in this manner are very common on skin and float fastenings.

Where the strength of each individual rivet is of considerable importance it is customary to form a round head such as shown in Fig. I-B. This requires that both the bucking iron and rivet set be provided with cups. Where it is desirable to make a rivet flush on one side, the countersunk rivet (Fig. I-C) or the dimple rivet previously mentioned (Fig. I-D) is used. If the material being riveted is thick enough, one sheet may be countersunk and a rivet with a countersunk head inserted from that side. The rivet shank is then headed, usually with a round head. It is possible to reverse this procedure, and inserting a round head rivet from the opposite side, spread the rivet shank with a ball peen hammer until it fills the countersink. The round head of the rivet should be supported with a cupped bucking iron, and the heading finished with the flat side of the hammer. A certain amount of filing will be necessary to produce a smooth job. The countersunk type of flush rivet is not satisfactory for thin sheets, as the flush head will not provide sufficient holding power. However, if the joint is dimpled, as shown in Fig. I-D, not only can sufficient head be formed but the entire joint will be strengthened. The dimpled joint is made by using a die and punch to press conical depression in the sheets to be joined. Where possible, a countersunk rivet should be used and a round head formed on the opposite end.

PNEUMATIC RIVETING

In general the procedure used when hand riveting is followed when using a pneumatic riveter. The main difference lies in the use of power driven equipment for upsetting or heading the rivet. A

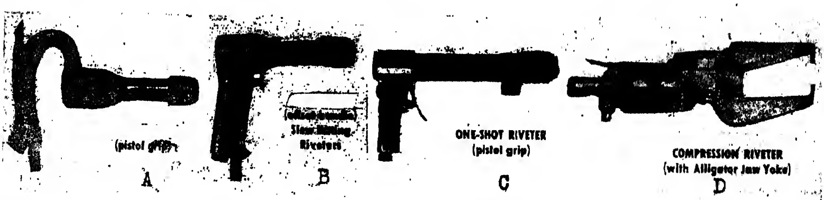


Fig. I

description of the operation of pneumatic riveters is given on the following pages.

Pneumatic riveters may be roughly divided into four classifications: the standard or fast hitting riveter, (I-A), the slow hitting riveter (I-B), the one shot riveter (I-C), and the compression or squeeze riveter (I-D). Each of the first three types is provided

RIVETING
(continued)

with interchangeable rivet headers or hammers which are similar to the hand rivet sets. These headers have cup depressions to fit or form rivet heads. The compression riveter is equipped with a header on each jaw. The stationary jaw serves as a bucking iron and the rivet is upset by the movable jaw. Fig. II shows a riveter of this type in use.

Fig. II

When using pneumatic riveting guns care should be taken to select the correct type of header. There are several methods for installing the header in the gun, but in the type of guns shown in Fig. I this may be done by simply unscrewing the coil spring from the end of the gun, inserting the header selected, placing the spring over the header and tightening it on the barrel.

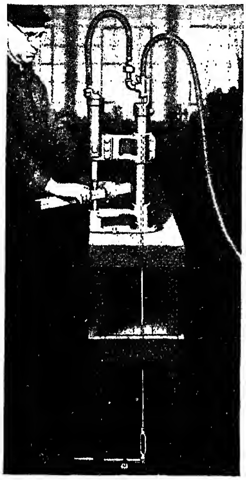
When actually operating the gun, the throttle or trigger should not be pulled until after the header has been firmly placed on the rivet, and the rivet is properly bucked. Carelessness in this respect may result in serious damage to the material. If the fast hitting gun is being used it should not be necessary to hold it on the rivet more than a few seconds, depending upon the size and material of the rivet and the type of head being formed. The throttle should be released before removing the gun from the rivet. If the operator is not thoroughly familiar with the action of the gun, several sample rivets should be driven in scrap material before attempting finished work.

Some fool-proof system of signals should be arranged between the riveter and the bucker so that there will be no possibility of the gun being operated on a rivet that is not bucked. This is especially true when using the one shot riveter.

When driving a long line of rivets, much time will be saved if several rivets are inserted in the holes and held in place by a strip of masking tape over their heads. The gun may be placed on the rivet without removing the tape, thus the tape serves a double duty: holding the rivets in place and forming a cushion to prevent the rivet header from damaging the material.

SMALL PNEUMATIC TOOLS

Practically all aircraft factories and many airplane repair stations are now using pneumatic tools of various types. Pneumatic riveters especially are gaining tremendous popularity. It has been found that a better, as well as a much quicker, job of rivetting can be done with the pneumatic riveter than can be done by hand.



Bench Riveter

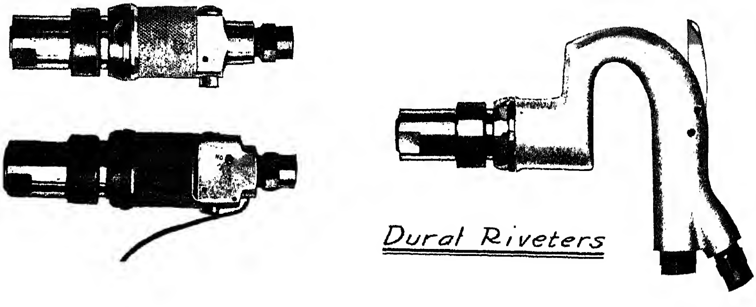
The photographs on this subject were supplied through the courtesy of one of the largest manufacturers of pneumatic tools, The Cleveland Pneumatic Tool Co. of Cleveland, Ohio.

THE BENCH RIVETER

For larger work, also for mass production, the bench riveter is very often used. Bench riveters are supplied in various types and sizes, to suit special jobs. As may be seen by the illustration, the bench riveter may be adjusted to various heights for different sizes of material. One of the greatest advantages of this machine is that it allows both hands free to steady the material, the throttle being operated by a foot treadle. Rivetting can be done without the aid of an assistant, as the machine is so arranged as to buck its own rivets. Various other types of pneumatic tools are supplied in bench mounting models.

HAND RIVETERS

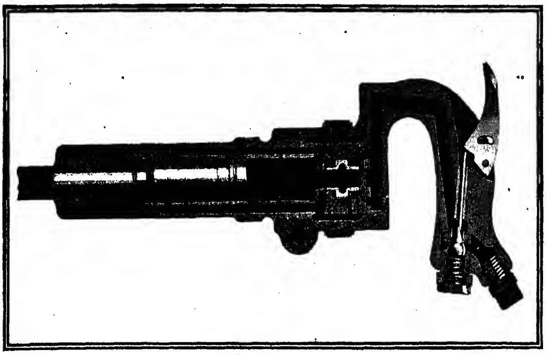
Assembly and repair work can be done more efficiently with the use of the portable pneumatic riveter. As most aircraft rivetting is comparatively light and is very often done in limited spaces, the riveter for this purpose should be small, light and compact. Three popular types for heading dural rivets are shown below. The rivet must be bucked with a separate tool.



Dural Riveters

SMALL PNEUMATIC TOOLS
(continued)

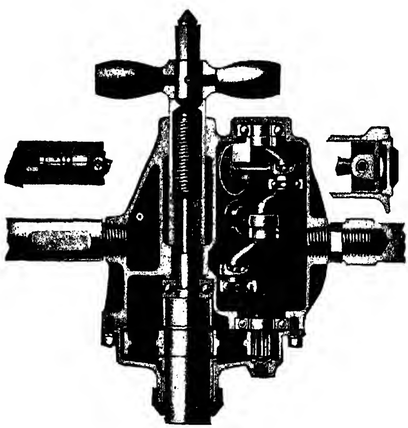
The pneumatic riveter operates on compressed air which is supplied from a compressor or air storage tank through a hose line to the tool. When the throttle or trigger is opened, the compressed air causes a plunger in the cylinder to be blown back and forth with great rapidity and force. As the air passes through the main valve (see the cross section drawing) the plunger is forced down, where it strikes a rivet header, which in turn imparts the impact to the rivet. Rivet headers are of course supplied with various size cups to make the correct shape head. The return stroke of the piston, or plunger, is cushioned by air, reducing the jar to the operator.



Pneumatic

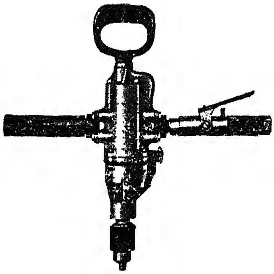
PNEUMATIC MOTORS

Pneumatic motors of the reciprocating type shown below in cross section, are used quite extensively to power rotary pneumatic tools such as pneumatic drills, sanders, surfacers, grinders, wrenches, etc. This motor is operated by compressed air acting on one, two, three or more pistons, similar to those in an engine. Tools powered with this type of motor have the advantage of controllable speed; for instance, a drill with a motor of this type will deliver almost as much power at low speed as it will at high. This is a feature which is almost impossible to duplicate with an electric motor. A rotary motor is very often used on the smaller rotary tools, as it can be made to occupy less space. As a rule, these motors are not as powerful as the reciprocating type.



Pneumatic Motor

SMALL PNEUMATIC TOOLS
(continued)



Heavy-Duty Drill

Angle Drill

PNEUMATIC DRILLS

Pneumatic drills of the types shown here are becoming increasingly popular. The feature of controllable speed is of considerable importance in heavy work. Where space is limited the angle drill is a great convenience.

PNEUMATIC SANDERS AND SURFACERS

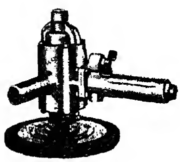
Pneumatic sanders, buffers, and surfacers are of considerable importance where time is an element. They are used on almost any job from buffing a metal propeller to removing paint.

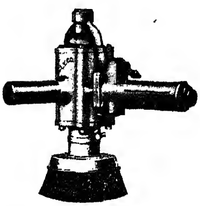
PNEUMATIC GRINDERS

Portable pneumatic grinders of the type shown below have a wide use in the grinding of castings, etc.

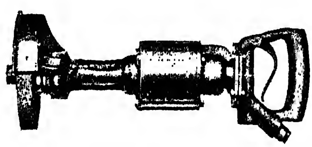
PNEUMATIC WRENCHES

Pneumatic wrenches are used to speed up production assembly work, both on the airplane and the engine. They are supplied with various size sockets to fit the standard aircraft nut. They are adjustable, to exert any desired tension on the nut. They are usually arranged so that the socket may be placed on the other end of a through spindle, and the wrench used for unscrewing.

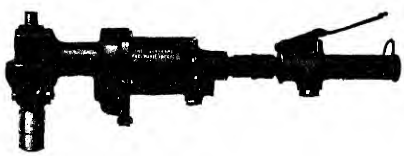




Surfacers



Portable Grinder

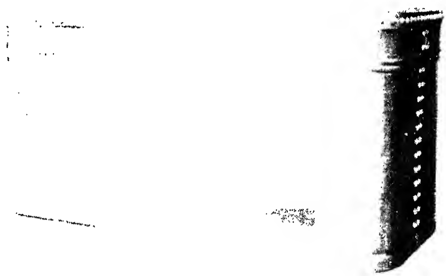


Pneumatic

HOW TO MAKE A TOOL BOX

Employers in many of the larger airplane factories require that prospective employees have an assortment of tools and a tool box of their own. The project described here not only provides such a tool box, but affords the mechanic an opportunity to show a prospective employer an actual example of his proficiency in metal work. The construction of a box such as shown in Fig. I allows the mechanic to demonstrate his skill in beading, riveting, forming seams, bending flanges on curves, rolling wire edges, making fittings, bending curves in sheets and many other similar processes.

This tool box is designed especially for airplane mechanics. It is sufficiently large to hold the most frequently used tools, and yet small enough to be convenient. The rounded corners present a pleasing appearance and permit a type of construction which is in strict accord with approved aviation practices. If the work is carefully and neatly done, the mechanic will have an example of his craftmanship of which he can justly be proud.



Since aluminum alloy (17S-0) is a standard aircraft material, it is recommended for the construction of this box. However, if this material is not available, terne plate of a lighter gage may be used.

MATERIAL: .030" Aluminum alloy sheet (17S-0) approximately 24" x 48"; 1/8" x 1/2" Round head aluminum alloy rivets (A-17S-T); 1/8" Soft iron wire, 48" long; 1/16" sheet steel (1025 or 4130) 2" x 8"; 2 small butt hinges; 1 leather trunk handle.

TOOLS: Metal layout and working tools, woodworking tools, bending brake or bar folder, rotary machine, riveting tools, assortment of hammers and mallets, drills, tin snips.

PROCEDURE:

1. Cut the material for the bottom of the box in one piece by squaring a sheet to the size 7-3/4" x 15-3/4".

2. Cut the corners to a 1-5/8" radius.

3. Mark a 3/8" flange around the entire sheet. The flange radius will be 1-1/4".

4. Using a brake, bar folder, or other suitable means, bend the side and end flanges to 90° (see section on Shaping Sheet Metal).

5. Prepare two bending blocks from hardwood with a corner radius of

HOW TO MAKE A TOOL BOX
(continued)

1-1/4". These blocks will be similar to those shown on page 143.

6. Bend the corner flanges, as described on page 143.

7. After the corner flanges have been bent to 90°, they will probably exceed the 3/8" flange width desired. Cut any excess material away and file the flange end level with the side flange. The bottom should now look as shown in Fig. II-A. (Note bending blocks clamped in position for making corner flange curve.)

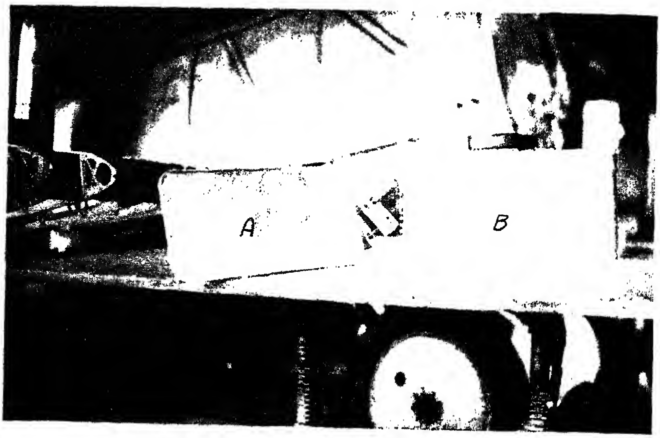


Fig. II

8. Prepare the top of the tool box in the same manner as was done for the bottom. However, the top of the box must be larger than the bottom in order to fit over the sides. The dimensions for the top are: (a) Overall 8" x 16"; (b) Flange 3/8"; (c) Corner radius 1-3/4"; Flange radius 1-3/8". Note: The top should be enough larger to allow for 3 thicknesses of the metal between the inside of the flange of the top and the inside of the flange of the bottom, plus about 1/64" to 1/32" more for clearance. In other words the inside dimension of the bottom is 7". The inside dimension of the top will be 7" + 3 times the thickness of the metal + about 1/64". The dimensions given here apply to 1/32" material. If a different gage is used the proper dimensions will have to be computed.

9. The sides or shell of the box is made in two pieces and joined with riveted butt seams. The seams are located in the middle of each end of the box. See Fig. I. The sides should be 7" high and about 21" long. The exact length is not given, for the sides must be fitted to the bottom in order to avoid making a mistake.

10. Mark a vertical centerline on each of the side pieces, as shown

HOW TO MAKE A TOOL BOX
(continued)

in Fig. III-(c), and match this centerline with the center of the bottom, as in Fig. III-(e). Clamp the material in this position and mark the location for the beginning of the bend on each end, Fig. III-(a) and (b).

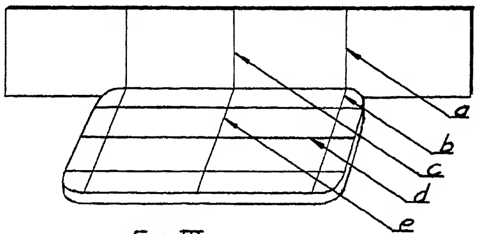


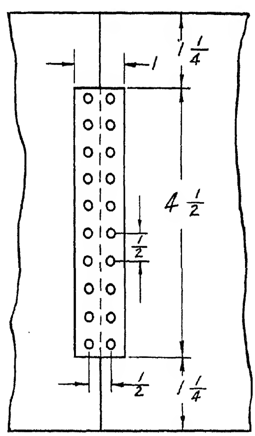
FIG. III

11. Shape the sides by bending each end to 90° over a 1-1/4" bending mandrel, as shown on page 137.

12. After the sides are curved to fit the bottom, clamp one side in position and mark each end to coincide with the longitudinal centerline of the bottom, Fig. III-(d). This is necessary to make sure the butt seam will be in the exact center of each end of the box. The side should be squared and cut at the points thus located. The cut should be trued with a file.

13. After the first side is prepared, clamp it in position and then fit the second side to the first. Great care should be taken to see that the ends fit exactly, as otherwise the neat appearance of the butt joint will be impaired.

14. The ends of the shell may now be joined. A 1" reinforcing strip, of the same material as the shell, should be used for this purpose. The reinforcing strip is 4-1/2" long and spaced 1-1/4" from each edge of the shell, as shown in Fig. IV. 1/8" Aluminum rivets, spaced as shown, are used for fastening the seam.



15. Place the bottom in one end of the shell (to hold it in shape) and run a 1/4" diameter bead, 1-1/16" from the other edge. (See page 150). A form, cut from 1/4" plywood, which fits snugly around the outside of the shell will preserve the curve on the corners when beading. This bead should be rolled in, or so the depression will be formed on the inside of the shell. (See

HOW TO MAKE A TOOL BOX
(continued)

cross section, Fig. V).

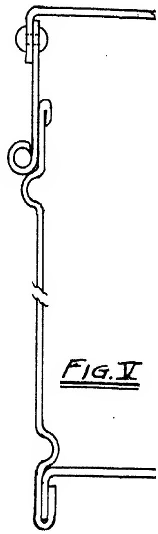


FIG. V

16. Remove the bottom, place it in the beaded end and bead the opposite edge of the shell, using the same rollers and gage setting. However, this bead must be rolled out, or opposite to the first one.

17. Before removing the bottom, measure the distance that the edge of the shell extends beyond the flange on the bottom. The bottom should be forced tightly against the bead when this measurement is taken. If the work has been done correctly, the distance from the edge of the flange on the bottom to the edge of the shell will be about 3/8".

18. Remove the bottom and, using the burring rolls, set the gage so that the bottom edge of the shell may be marked to bend toward the inside. The gage setting will be the same as the measurement obtained in No. 17. The purpose of this operation is to make a definite bend line in order to prevent the material from buckling while completing the standing seam. Do not attempt to make a bend of more than two or three degrees, or it will be impossible to put the bottom in the shell.

19. Replace the bottom with the flanges down and complete the standing seam, as described on page 154.

20. After completing the standing seam, the top of the shell should be marked 3/16" from the edge, and this flange hemmed, or folded against the sides, as shown in Fig. V.

21. To make the edge for the lid, cut two strips of metal 1-1/2" x 24".

22. These strips should be riveted together with a butt seam. The reinforcing strip should be 3/4" from one edge so that it will not interfere with the rollers.

23. Roll a 1/8", or 5/32" diameter wire in one edge (see page 151).

24. Cut the ends of the strip square so that they may be joined with a butt seam, as was the shell. The butt seams should coincide with the location of the seams of the shell, as shown in Fig.I.

25. Rivet the strip into position, using 1/8" rivets spaced on 3/4" centers. (See Fig. I and Fig. V).

26. Two small butt hinges may be used to hinge the lid to the shell. They may be riveted in place, as shown in Fig. II-B. If this method is used, the bead will have to be cut away in order to

HOW TO MAKE A TOOL BOX
(continued)

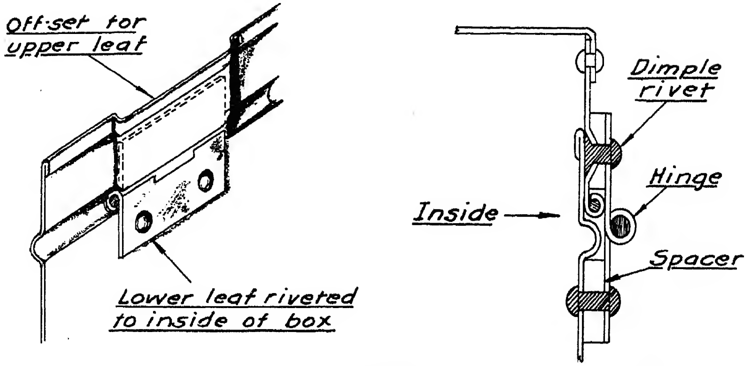


FIG. VI

allow the lower leaf of the hinge to be riveted to the inside of the shell. An offset will have to be formed in the upper flange of the shell to allow the top leaf of the hinge to fit flush with the exterior of the shell, as shown in Fig. VI-A.

Another method of attaching the hinges is shown in Fig. VI-B. Although this latter method does not make as pleasing an appearance as the other, it is stronger, for the bead does not have to be cut. The installation is simpler, as less fitting is required. The spacer plates are made to fit the leaves exactly and are of a thickness equal to the diameter of the wire edge.

27. A suitable hasp may be made from 1/16" steel. Dimensions for this are given in Fig. VII. The lugs are rolled around a 1/8" soft iron wire. The wire should be peened on both ends to prevent removal.

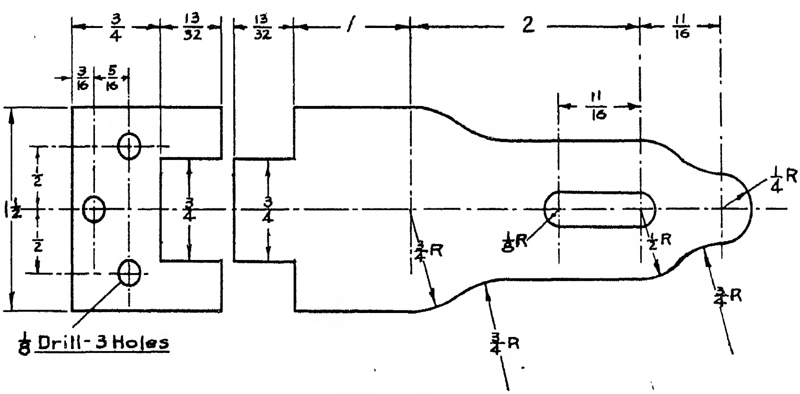


FIG. VII

HOW TO MAKE A TOOL BOX
(continued)

28. A staple may be formed as shown in Fig. VIII. A 3/16" soft steel rod is bent, as shown, and fastened to the plate by peening.

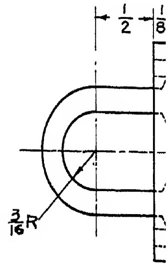


FIG. VIII

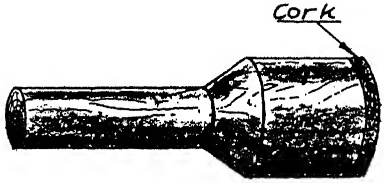
29. The hasp should be located on the lid, as shown in Fig. I and riveted in place. Care should be taken to see that the hasp is penpendicular.

30. After the hasp is in position, locate the staple by closing the hasp over it. Mark the location of the staple and rivet it in place.

31. A handle such as that shown in Fig. I may be purchased from almost any hardware store and riveted in place. If desired, a pair of small trunk locks may be purchased and installed on each side of the hasp. They will require spacer plates to raise them flush with the bead and wire edge.

This completes the tool box, except for the parts tray. Utilizing the types of construction employed on the tool box, there should be no difficulty encountered in designing and building a tray to suit your own individual needs.

An attractive finish may be secured by giving the box one coat of red oxide primer and, after it is thoroughly dry, applying a coat of crackle lacquer. Another attractive finish can be obtained by "spotting" the aluminum. The surface may be spotted by spinning a series of overlapping circles on the material. The circles are made by a spotter, Fig. IX, held in an electric drill. Such a device can be made in a wood turning lathe. The face of the spotter is dipped into a mild abrasive such as rouge or carborundum dust, and then pressed while rotating against the aluminum. The "spots" can be put on at random, but a better appearance can be obtained if a symmetrical layout is made in which each spot overlaps the adjacent ones a definite amount. A little ingenuity and practice on scrap material will disclose a satisfactory method of procedure with the equipment available. A coat of clear lacquer should be used to preserve the finish.



COWLING

In its broadest sense, cowling is any falsework enclosure the purpose of which is to lessen the air resistance. However, it is usually understood, and will be considered in this book, to be a removable metal fairing around the power plant or cockpit.

The early airplanes had no cowling, the engine and occupants of the ship being left exposed to the breeze. As performance improved and greater speeds were attained, this arrangement was soon found to be both inefficient and uncomfortable. The advent of water-cooled engines brought radiators, which were set up in front of the cowling. It was then found that due to the thickness and inefficiency of the propeller blades near the hub, the radiator could be made smaller and hence lighter, if placed somewhere other than between the propeller and the front cylinders of the engine. By decreasing the radiator area and streamlining the forward portion of the engine, resistance was decreased and performance proportionately increased.

When fixed radial air-cooled engines first cane into use, designers were afraid to use any cowling around the cylinder heads less the cooling be impaired. In fact, like most new things, air-cooled engines were regarded with more or less scepticism. The cowling covered only the crankcase and lower part of the cylinders while the rest of the engine was left exposed. The resistance of these exposed parts was, of course, high, and for a time it seemed likely that water-cooled engines would be restored to favor because of the possibility of keeping the resistance down.

However, experiments were made by various agencies, notably the National Advisory Committee for Aeronautics, and after much research the type of cowling for radial engines known as the N.A.C.A. cowl was developed. Practically all ships are equipped with this type of cowling today, as it reduces the drag of an air-cooled engine to that of a liquid-cooled when the radiator is included with the latter. The liquid-cooled type still has the advantage if wing radiators are used (see Power Plants) but these are not practical for general use and are found only on racing ships such as the record holding Italian Macchi.

A modified form of the N.A.C.A. cowling is sometimes found where it is desired to keep down the expense. This consists of a comparatively narrow ring of sheet metal around the cylinder heads and is called a Townend or anti-drag ring. This is shown in Figs. II and V. These sketches are taken from N.A.C.A. report No. 414, to which anyone interested can refer for more complete information. The illustrations show two types of noses with and without the addition of cowl rings. Only the upper half of the front section of the fuselage is shown as the lower portion is the same. The various combinations were all tested on the same airplane and engine and the figures given show the actual speed on the test runs. The cooling was satisfactory on all of the types shown. Fig. VII shows how the best arrangement (Fig. VI) looks from the outside. It was found that on a Wasp-powered ship, a ring 9" wide increased the speed 9 m.p.h. and a ring 21" wide increased the speed 16.4 m.p.h. Making the ring more than 21" wide did not produce any

COWLING
(continued)

further improvement in the performance.

Cowl rings of the wide type are usually spun from aluminum and this manufacture is not within the scope of the airplane mechanic's work. The narrow rings, however, are usually made from a strip of aluminum bent to a circular (or cylindrical) shape and then hammered to a curved cross section approximating the top comber of an airfoil. Both types are usually split at the bottom so they can be sprung apart and removed from the engine. Sometimes they are split at two points so that they come off in halves. They are usually supported on the rocker-box covers of the engine. Small aluminum cups are made to fit the rocker-box covers and rivetted to the ring. A felt pad is inserted at the bottom of the cup to prevent chafing. Needless to say, these rings are securely fastened, as it would probably be disastrous if one should come off and blow back.

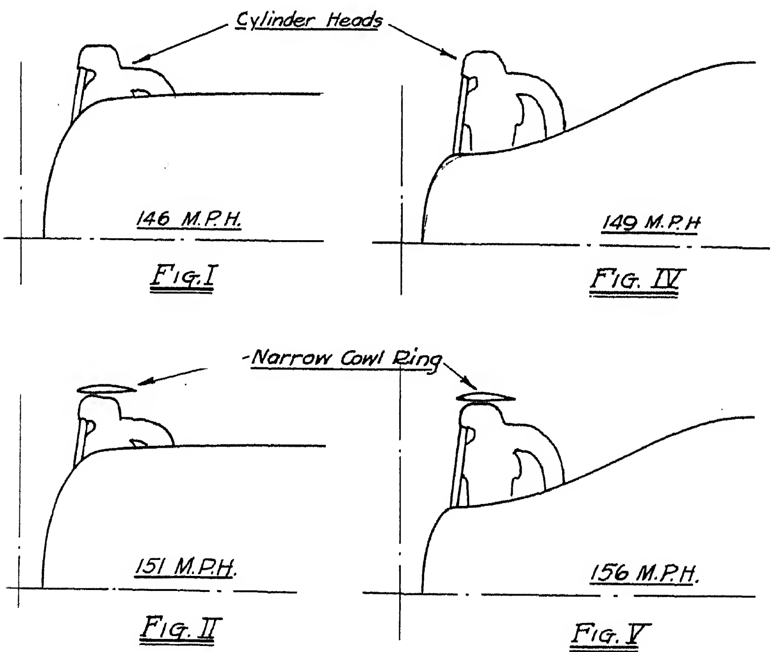


FIG. I

FIG. IV

FIG. II

FIG. V

COWLING
(continued)

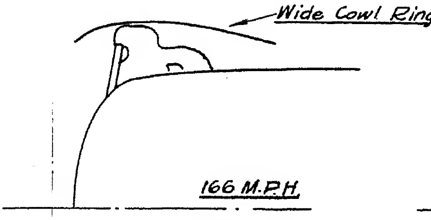


Fig III

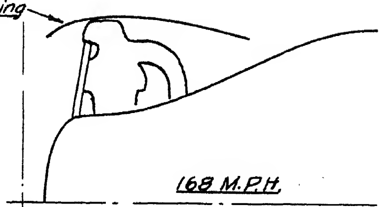


Fig VI

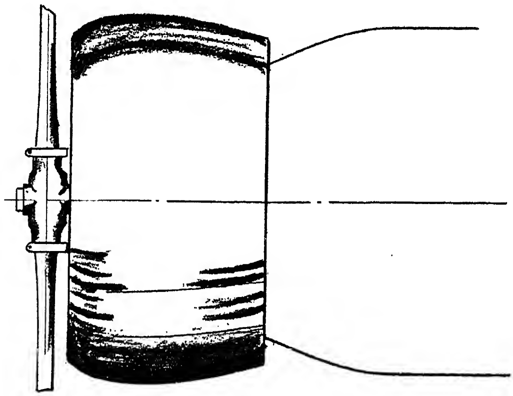
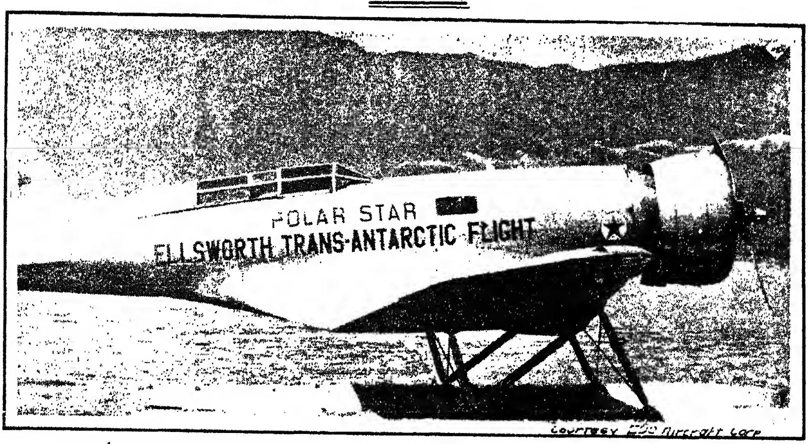


Fig. VII



Courtesy EDO Aircraft Corp

Typical N.A.C.A. Cowl on Northrop equipped with EDO floats

COWLING
(continued)

The foregoing general types of cowling are conventional and are found on most airplanes equipped with radial engines. Constant research is being conducted, however, to obtain lower resistance, better cooling, or both. Two methods of obtaining these improvements are discussed below. These designs have not become standard at the publication date of this book but are shown to indicate the trend of design and to familiarize the reader with the principles involved.

The rounded nose of the N.A.C.A. cowl tends to deflect some of the air outward and cause a decrease in pressure, or a partial vacuum around the forward portion. This action in the air is similar to that of an airfoil section, discussed later. Fig. VIII shows the section through one side of an extreme form of N.A.C.A. cowl and the air pressure around it. The distance of the boundary lines (of the low and high pressure areas) from the cowling shows the relative amount of the suction or pressure, the suction being, of course, in the negative or low pressure area. From this it may be noted that the suction is near its maximum at the extreme forward portion of the cowling.

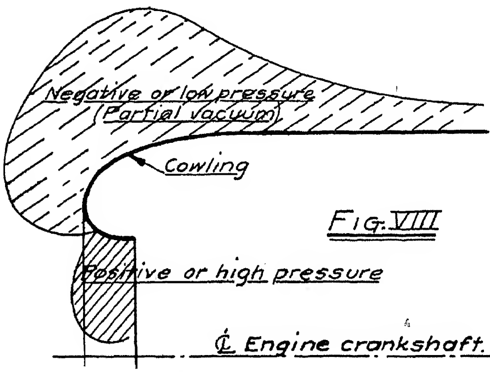


FIG. VIII

Utilizing this fact, the N.A.C.A. produced a cowling similar to that shown in Fig. IX. In this type of cowl, the air enters through the center as usual, but instead of passing out through an opening in the rear, is directed, by means of suitable baffles, around the cylinders to the rear of the engine, whence it is sucked forward again, across the cylinder heads and out through an annular opening in the nose of the cowl ring as indicated by the arrows. This type of cowling has been found to be much more effective at low speeds than the other types previously shown. On seaplanes, this feature is a distinct advantage, since such ships often must taxi for fairly long periods with high engine r.p.m., while the ship is moving comparatively slowly.

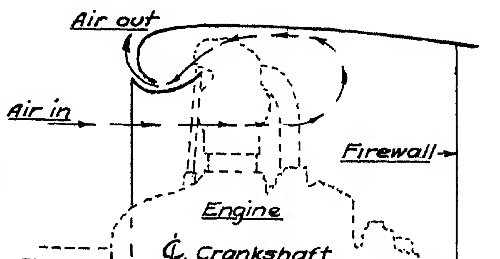


FIG. IX

Another type of cowling, used on the Curtiss P-42 pursuit ship previously illustrated, is shown in

COWLING
(continued)

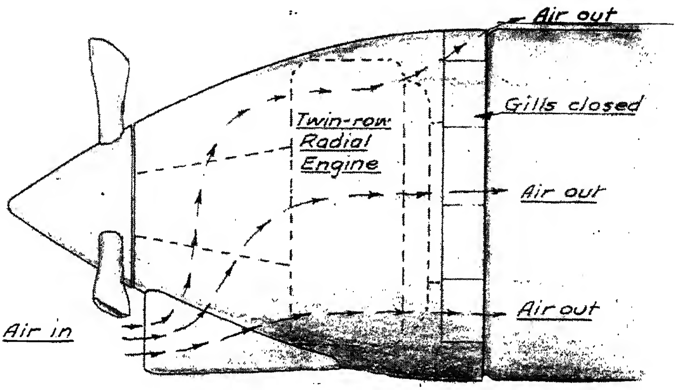


FIG. X

Fig. X. In this type the cooling air is brought in through a scoop on the bottom near the front and led out conventionally through an annular opening in the rear. The opening in the rear is provided with a shroud or gills which may be opened to provide a certain amount of suction and hence increased flow of air at low speeds. The shroud is common equipment on the more expensive airplanes, but the remainder of the cowling is unusual in that there is no appreciable opening around the propeller shaft. The propeller is provided with a large spinner which completely fairs the hub and entire nose of the ship. Fig. XI shows a three- quarter front view of the ship, from slightly below, with the gills open.

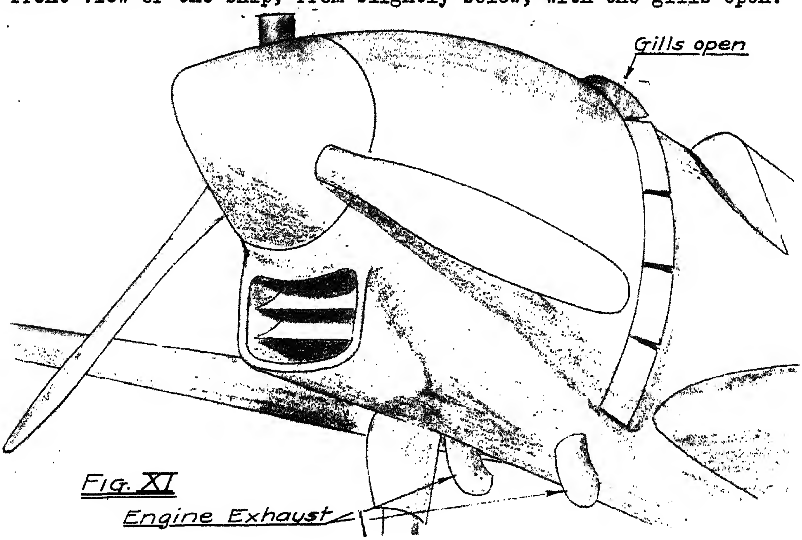


FIG. XI

Engine Exhaust

COWL REINFORCEMENTS

Large sections of cowling tend to vibrate and crack if not properly supported by reinforcing members. Also, the edges are easily bent and distorted unless they are stiffened in some way. Furthermore, even though the sheets are reinforced, it is not desirable to make them too large, especially in regions where they are likely to be removed frequently, such as around the power plant. One of the most satisfactory means of dividing and at the same time supporting cowling is by the use of the beaded channel shown in Fig. I. This shows, in addition to the channel, a section of cowling with the edge reinforced by rolling over a hard steel wire about 1/8" in diameter. The reinforcing grommet and cowl stud, through which a safety pin is inserted, are also shown. If possible, the channel should be made of heat treated dural at least 1/16" thick.

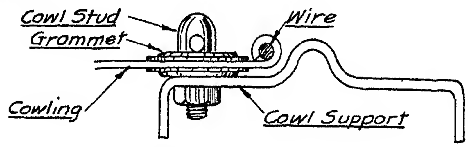


Fig. I

Fig. II illustrates four satisfactory methods of stiffening large sheets of cowling. The U-shaped stiffener is better but somewhat more difficult to apply. It should be made of duralumin, as should also the angle. If the cowl sheets are thick enough to permit the rivets to be countersunk, a neater job will result. Countersinking should not be attempted in material less than 1/16" thick, and even then the rivets should be spaced closer than they would be if not countersunk. If it is considered worthwhile to use the dimpled type of joint shown under "Sheet Metal Fastenings", a perfectly smooth job will result. Do not attempt this, however, without proper punches and dies, as otherwise the metal will be distorted and look worse than if no countersinking had been used.

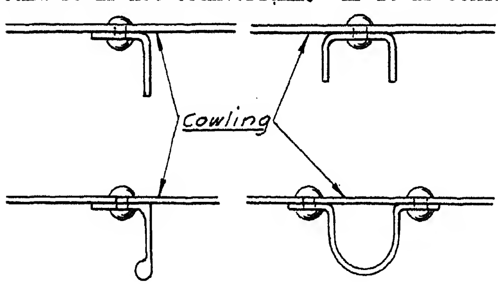


Fig. II

Sharp corners on any reinforcements should be avoided, as work is often done on parts of the power plant without removing all of the cowling. Since there is usually none too much room in the engine section, any projections are likely to cause scratched hands and skinned knuckles.

The rolled edge shown in Fig. I is ordinarily used to finish off the edge and at the same time reinforce it and prevent cracks. It is not difficult to make this type of edge if the metal is soft and a rotary machine is available. Full instructions for making such a finish have been given previously, on page 151.

HOW TO MAKE A STREAMLINE COVER PLATE

A simple introduction into bumping metal is found in making a streamline cover plate, Fig. I. It requires little material and the use of only a few tools and can easily be made from the instructions on this page.

FIG. I

MATERIAL: One piece of dead soft aluminum .040" x 3" x 6"; hardwood block at least 2" x 3-1/2" x 8"; a few 3/4" flat head nails, fine emery cloth, fine steel wool, sandpaper.

TOOLS: Plane, wood gouge, try square, tin snips, small ball pein hammer, dividers, 3/32" drill.

PROCEDURE:

1. Surface plane one face and the two edges of the hardwood block.

2. On the surfaced face, trace a 5" streamline shape, Fig. II.
Note: By referring to the sheet on "Streamline Struts" a streamline shape can be drawn on paper and then transferred to the board. By skipping every other ordinate, the layout will be simplified.

3. Square three lines across the face, as shown in Fig. II.
Note: The middle line is drawn through the point of greatest width of the outline.

4. Square these lines across each surfaced edge.

5. Trace one-half of the streamline outline on each edge, as shown in Fig. III.

6. With the wood gouge, hollow out the face of the block to the depth indicated by the layout lines on the edges. The cross section should present a symmetrical curve at any point.
Note: A little judgment will have to be used in gouging out the block, but remember the block should be hollowed out so that the cover plate can be bumped into the hollow forming the streamline cover shown.

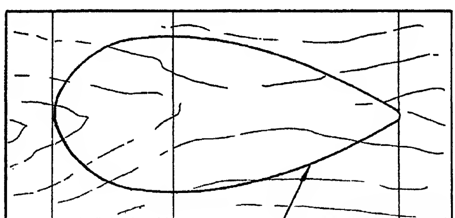


FIG. II

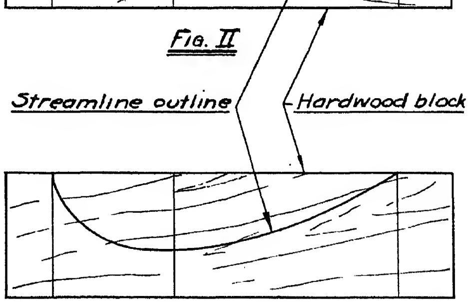


FIG. III

HOW TO MAKE A STREAMLINE COVER PLATE (continued)

7. After the block has been gouged out to the desired shape, sand the hollow to make sure that no dents or high spots remain. This is extremely important, as any defect in the block will show in the finished work.

8. Place the aluminum over the hollow, making sure that at least 1/2" extends over all sides, and with a few 3/4" nails, nail the aluminum into place.

9. Using the round end of the ball pein hammer, bump the aluminum into the hollow.

Note: It must be remembered that in order to force the aluminum into the hollow, the metal must actually be stretched, therefore a number of light taps with the hammer are required, as a heavy blow would only tear the material. The bumping should be started by tapping the aluminum around the edges first and gradually working down into the center. Never attempt to work too fast, but rather stretch the material into the hollow by bumping it only as fast as it works against the sides of the cut.

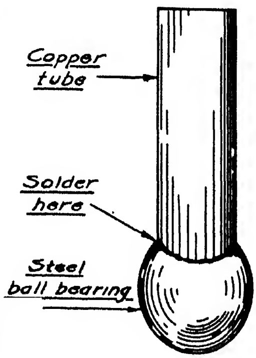


FIG. IV

10. After the bumping is completed, the hammer marks should be removed. This can be done by rubbing with the round end of the hammer. A better tool for this purpose can be made by soldering a large diameter ball bearing to a copper tube handle, as the ball bearing will have less tendency to scratch the aluminum, Fig. IV.

11. When all the hammer marks are removed from the material, the plate may be removed from the block.

12. Make a 3/8" flange around the cover by scribing this distance with the dividers, as shown in Fig. I.

13. Cut along the scribed line with the tin snips.

14. Drill 3/32" holes spaced about 3/4" apart.

15. Polish the streamline cover plate with fine emery cloth.

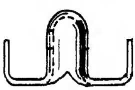
After the cover plate has been finished and polished, it should be inspected for any possible dents or high spots. The flange should be inspected to see that it is perfectly flat and that the raised cover portion forms a definite angle with the flange. If any of these faults are apparent, smooth out the bumping block and try it again.

COWL FASTENINGS

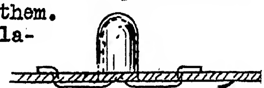
Every airplane manufacturer has his own ideas about cowl fastenings, just as every make of automobile has its own type of hood latches.

However, there are certain fastenings which have become as nearly standard as anything in the industry and it is these which this sheet deels with. There are few airplanes in which they do not appear in one place or another. The cowling stud with the screw thread is a stock accessory which may be purchased from any dealer in aeronautical supplies. This type is machined from bar stock, is solid, and is usually made of steel. The installation is obvious, consisting simply of drilling a hole the size of the threaded portion, inserting the stud, and putting on a lock washer and a nut. Another type is sometimes found which is a hollow stamping, and is, of course, lighter than the threaded type. To install this one, three holes are drilled, one to fit the stud proper and the other two to fit the turned-up tabs. The stud is pushed through from the inside of the cowl support, the two tabs coming out through the holes which have been drilled for them. Then the tabs are bent down and the installation is complete.

Cowl Stud Screw

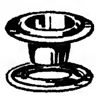


Cowl Stud ype



Cowl Support

Where the cowling fits over studs, it will wear out rapidly unless the hole in the cowl is protected by a grommet. Grommets are usually made of soft brass and when they become worn, they can easily be replaced. The installation is simple. A hole is drilled in the cowl large enough for the shank of the grommet, the grommet pushed through from the outside, the washer slipped on the shank and the shank spread over the washer with a ball-pein hammer, or with a special grommet die, which makes a neater job.

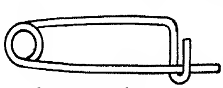


Grommet

The cowling is held in place with a cowling clip inserted through the hole in the stud, or if there are several studs in line, a similar device but much longer, called a cowling pin is used. At points where it is extremely important that the fastening remain in place a safety pin is used. An assembly of stud, support, grommet and cowl is shown in the sheet on "Cowl Reinforcements." There is no clip nor pin shown in this illustration, however.

Cowling Clip

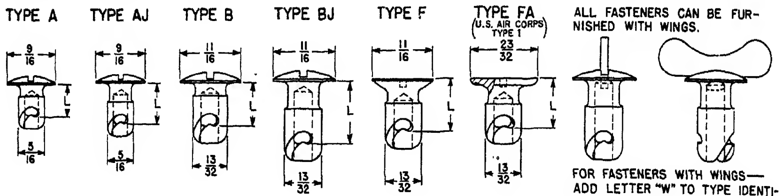
When using a clip, it should be inserted in the hole until the first "hump" snaps over the cowl stud, and if possible the point should be toward the rear. It may not appear to be very secure, but they seldom come out, and even if one should work loose there are usually plenty more to hold the cowl on.



Safety Pin

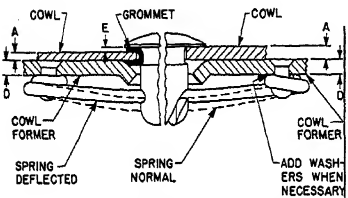
COWL FASTENINGS
(continued)

One of the most satisfactory types of fastener is that made by the DZUS FASTENER CO., INC., of Babylon, N. Y., by whose courtesy the following illustrations and information are supplied. This fastener may be installed so that it is absolutely flush with the cowl, and may be opened readily with a screwdriver or even a small coin yet it holds securely when locked. It may also be obtained with a wing which eliminates the use of any tools. It has no loose parts to be misplaced, is exceptionally neat in appearance and simple to install. The accompanying illustrations are self-explanatory.



ALL FASTENERS CAN BE FURNISHED WITH WINGS.

FOR FASTENERS WITH WINGS—ADD LETTER "W" TO TYPE IDENTIFICATION OF THE DESIRED STANDARD FASTENER.



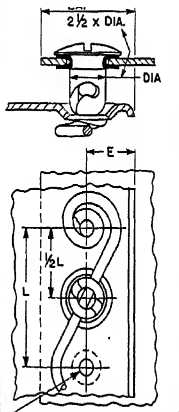
TYPE A & B INSTALLATIONS

LEFT SIDE—WITH GROMMET RIGHT SIDE—WITHOUT GROMMET

THE REQUIRED LENGTH OF FASTENER = A + D + E + HEIGHT OF SPRING − DEFLECTION OF SPRING. (OMIT "E" WHEN FASTENERS ARE USED WITHOUT GROMMETS).

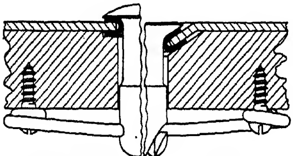
STANDARD SPRING INSTALLATION

TYPICAL VIEW FROM INSIDE SHOWING OVERLAP



DRILL #30 & C'SINK ¼ DIA X 110° FOR R. H. RIVET

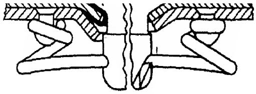
FOR TYPE A E = ⅜ MIN.
FOR TYPES B-F-FA



TYPE AJ & BJ INSTALLATIONS TYPE FJ INSTALLATIONS

IN THIN PLATE WITH STANDARD GROMMET

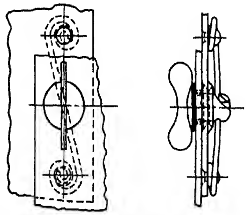
TO FIND REQUIRED LENGTH = FOR TYPES AJ & BJ USE SAME METHOD AS FOR TYPES A & B. FOR TYPE FJ USE SAME METHOD AS FOR TYPE FA.



TYPE F INSTALLATION

LEFT SIDE—WITH STANDARD GROMMET RIGHT SIDE—WITHOUT GROMMET

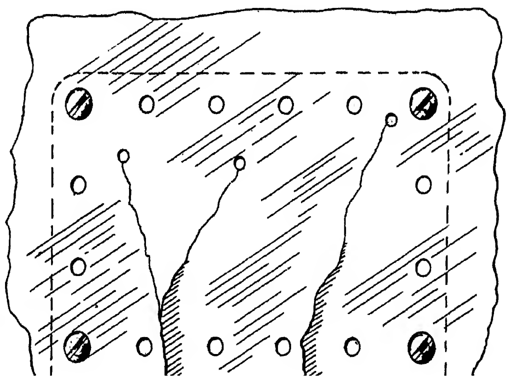
TO FIND REQUIRED LENGTH = USE SAME METHOD AS FOR TYPE FA.



LOCKED POSITION OF WING TYPE FASTENERS (WHEN USED WITH STANDARD SPRINGS)

REPAIRS ON COWLING

There are several types of repair jobs on cowling which may become necessary from time to time. They may be grouped into three general classes: cracks, holes, and dents, the most common of which is shown in Fig. I, which illustrates cracks beginning at the edge of a piece of cowl. Cracks may also start at the rim of a hand hole or any other place where it has not been desirable to roll in a wire as shown in "Cowl Reinforcements".



Cowling should be inspected frequently for cracks and when they are observed no time should be lost in repairing them, as shown in Fig.I. To begin with, holes of about 3/32"diameter should be drilled at the end of each crack to prevent its extending farther. A reinforcing plate of dural of approximately the same thickness as the cowl and large enough to extend well beyond the damaged portion should be rivetted on the inside using small, flat head or binder head aluminum rivets with the head on the outside. Great care should be taken to prevent denting or bending the cowling when heading up the rivets. It will be found helpful to drill the corner holes first and attach the reinforcing plate with machine screws, which should be left in until the rivets have been headed up in all the other holes.

Holes in cowling do not usually occur accidentally, but are the result of some change such as the installation of a direct electric starter in place of a hand inertia type, which leaves the hole where the crank went through. Such holes should be patched following the same procedure as outlined above.

Dents in cowls should be carefully hammered out by placing the concave side of the dent on a smooth surface and tapping the convex side with a rawhide or wooden mallet. The paint will probably chip off during this process. The bare spot should be sanded, prin ed, and successive coats of sanding surfacer applied and rubbed smooth with fine sandpaper until the damaged area is no longer noticeable. Then the section should be sprayed with the original color. If sufficient care is used, the hob will be completely disguised so that it will be impossible to tell that any damage has ever been done.

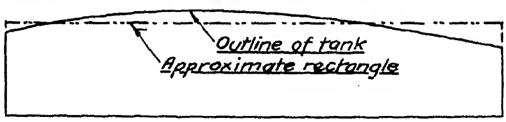
TANKS

Tanks are used ordinarily in airplanes only for gasoline, oil, and water. Except in large transport ships where water is carried for drinking and bathing, water tanks are used only in liquid cooled engines, either as part of the radiator or as a separate header tank, connected with the cooling system. In any case, they do not differ from gas tanks materially except in the size of the connections, and, therefore, will not be specifically discussed here. The installation of radiators is taken up in the Power-plant section.

Tanks are made of several different kinds of sheet metal - terne-plate, aluminum, duralumin, and stainless steel, with the first two predominating at present. Of these two, aluminum is by far the most widely used because of the saving in weight, though it is much more difficult to repair, due to the fact that as yet no satisfactory means has been developed for soldering it, and a leak at a seam means that the tank has to be taken out and repaired by an expert. In this connection, NEVER USE A TORCH on a tank which has had gasoline in it at any time, regardless of how long it has been empty, unless the tank has been thoroughly blown out with live steam, or else filled with carbon tetrachloride (fire extinguisher liquid) and rinsed out well. Even then, use the greatest possible caution, as gasoline fumes have a way of remaining in tanks supposedly empty for six months, and if there are any fumes present a serious explosion is almost certain to occur. Terne-plate tanks may be soldered with a soldering iron without much danger, but this is, of course, impossible on aluminum construction.

The capacity of tanks with comparatively straight sides is, of course, quite simple to calculate, being merely the length times the width times the depth, divided by 231. The dimensions should be in inches, and the answer will be in gallons, since there are 231 cubic inches in a gallon. As an example, take a tank 23" by 20" by 6". The capacity in gallons is $\frac{23 \times 20 \times 6}{231} = \frac{2760}{231} = 11.9$ gal.

If one end of the tank is a circle or an ellipse, the area of the end must be worked out and multiplied by the length to obtain the volume. The volume of course must be divided by 231 to convert to gallons. The area of a circle is $3.1416 \times \text{radius}^2$ or $.7854 \times \text{diameter}^2$. The area of an ellipse is $.7854 \times W \times D$, where W and D are the width and depth of the ellipse. If the tank is to fit into a wing and conform to the shape of the wing section, it is usually accurate enough to consider the section of the tank as rectangular. The depth of the rectangle can best be approximated by laying out the section of the tank and then drawing the rectangle on top of it, as in Fig. I.



If there are a number of irregularities in the shape of the tank, as is often the case when it has to be fitted into constricted locations, it is best to break it up into several sections of approximately regular shapes and figure each section separately, then add to find the total.

TANKS
(continued)

Gasoline tanks should be provided with a sump or depression at the lowest point. See Fig. V. The drain should be at the bottom of the sump and should be piped to some point outside the ship, so the tank can be emptied into a can of at least five gallon capacity. Greatest care should be taken that the drain plug or cock is thoroughly safetied. The feed line should have its opening slightly above the bottom without going into the line. The tank should be drained at reasonable intervals so that any accumulated foreign matter will be removed.

The drain on oil tanks should be at least 1" in diameter, as cold oil will run very slowly. Also the drain plug should be on the outside of the cowling, or else readily accessible through an inspection door, as oil has to be drained every twenty to twenty-five hours, and should be drained every night in cold weather and heated before replacing. Needless to say, the drain plug should be safetied with just as much care as the tank drain. To lose either oil or gas means a forced landing, but if it is the oil that is lost, it may mean a ruined engine as well. The most satisfactory method of safetying plugs is to drill a hole through the square end of the plug, pass safety wire through the hole and twist the wire around some convenient projection, NOT around the drain pipe. It is customary to solder a small lug with a hole in it onto the drain pipe and pass the safety wire through the hole. If drain cocks are used, a hole should be drilled through the handle, to be used for the wire, which is then fastened to the nearest convenient fixed point.

Tanks of more than ten gallons capacity, if they are thin and flat, should be provided with baffles. The same applies to those of approximately cubical shape of the capacity of more than twenty gallons. The baffles serve the double purpose of preventing the liquid from surging back and forth in sudden maneuvers and of reinforcing the walls of the tank. In welded aluminum tanks, they also tend to lessen buckling of the plates as they are welded.

Filler necks should be large and accessible. The caps should fit tightly and securely, and in addition should be anchored to the neck by a chain, so that if they should come off they will not blow back into the controls or the pilot's face. The filler neck on oil tanks should be so located that it is impossible to fill the tank within 10% of its total capacity. This is a Civil Aero. Authority regulation, and is made necessary by the fact that oil expands when it is heated and if the tank is entirely full, the oil will either overflow out of the vent or load up the engine. Filler caps must be plainly marked with the capacity of the tank in gallons. Both oil and gas tanks must have vents to allow the air to enter as the contents of the tank are used up. It is standard practice, however, to connect the oil tank vent with the crankcase of the engine, and thus vent through the crankcase breather. This prevents any oil which may foam out of the tank being blown all over the ship, and possibly its occupants, which besides being annoying, is an unnecessary waste. Care should be taken that neither gas tank nor oil tank vents become clogged.

TANKS
(continued)

Felt should be placed between any tank and its supports and tie-down straps, if such are used. Straps or fastenings should be tightened with great care, as otherwise the tank may shift around and cause leaks in the connections or chafe through from rubbing against some part of the ship. Fig. II shows a typical tie-down strap.

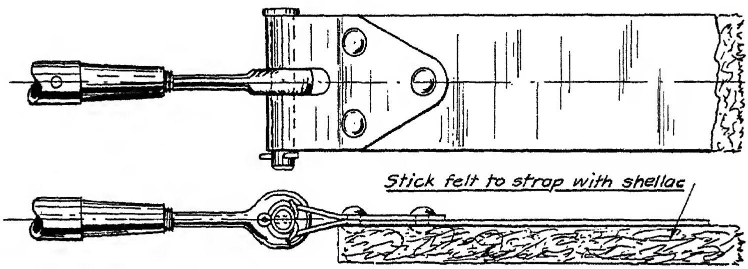
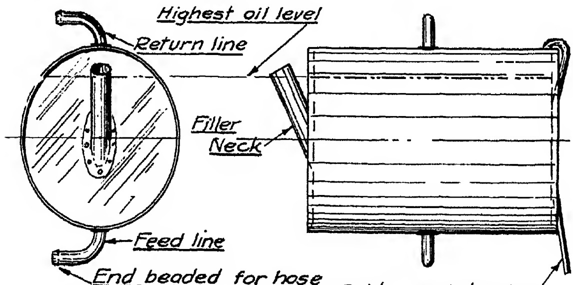


Fig. II

It is entirely within the range of a field mechanic's facilities to make or repair a terne-plate tank such as the oil tank shown in Fig. III. The material, which is sheet steel coated with a mixture of tin and lead, is easy to solder. The rivets are used simply to strengthen the seams. Copper rivets are more easily headed up and soldered than steel and for that reason should be given preference. The lock type of seam is somewhat harder to make but is less likely to develop leaks. No rivets are needed with this type of seam. A terne-plate tank may be patched if necessary simply by soldering a piece of the same material over the hole. If the hole is large, or on the bottom of the tank, the type of patch illustrated in Fig. IV is more desirable. This patch may also be used on aluminum tanks in an emergency, by placing a gasket of cork or vellumoid between the patch and the original material, and spacing the machine screws about 3/8" apart. Lock washers should be used under the nuts in this case as they cannot be soldered.



Alternative Seams

Fig. III

TANKS
(continued)

The fittings and connections on the terne-plate tank are rivetted or bolted on, the heads of the rivets or machine screws soldered and also the nuts. All corners of the fittings are also soldered. In aluminum tanks the fittings are either made of alum-

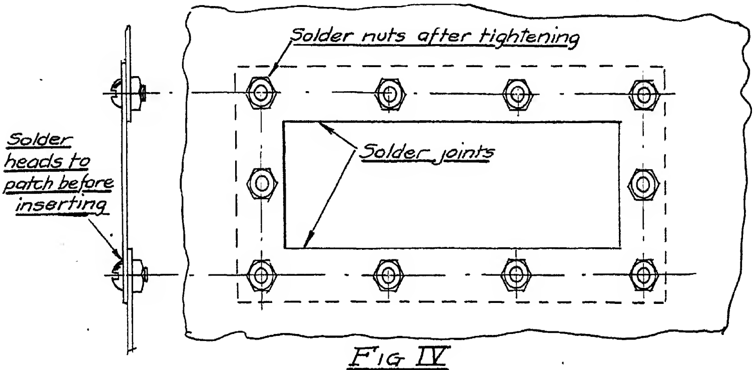


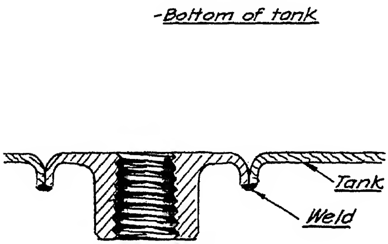
FIG IV

inum and welded in, or bolted in place with machine screws, the heads of which have been brazed or silver-soldered to a split ring of steel. Both types of attachments are illustrated. The steel ring may either be cut at one point and worked into the hole, or made into two separate halves. If the bolted on type is used, a gasket must be inserted between the fitting and the tank.

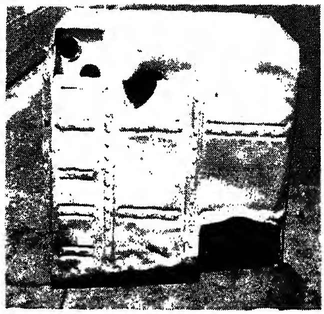
Duralumin tanks have been tried out but without much success, due to the fact that the joints must be rivetted and it is difficult to prevent leaks. Duralumin can be welded but the welding destroys its strength and resistance to corrosion unless it is heat-treated afterwards, and this is usually not practical. The latest development in tanks is the use of stainless steel, shot welded at the seams with the welds overlapping. See Fig. VI. This type of construction is ideal as the material is of extremely high strength and stiffness and highly resistant to rust or corrosion. Tanks made in this manner are as light as any others yet produced, are practically everlasting, and by using a special flux may be soldered successfully should any holes be punched in them. They cannot be built by a field mechanic, as the welding process is very complicated, but they may be repaired in the same manner, and almost as easily as a terne-plate tank. Brass and copper are sometimes used for tanks, especially in liquid-cooled systems, as they, of course, do not rust and can be easily soldered. Terne-plate, even though the steel is coated with a non-rusting material, will rust after a time when used to carry water. The procedure in making brass or copper tanks is identical with that used in the case of terne-plate. Brass is stiffer than copper as a rule, and hence makes a somewhat stronger tank. On the other hand, if there is any need for "bumping" or forming the surface of the tank to a double curve, copper is much more ductile and can be hammered into any conceivable shape by a good coppersmith.

TANKS
(continued)

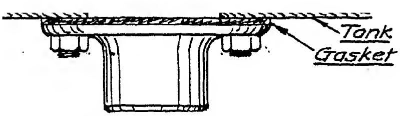
Fig. V shows typical construction in a welded aluminum tank. The corrugations are used to allow expansion when the welding is done and thus eliminate buckling of the walls.



WELDED FITTING

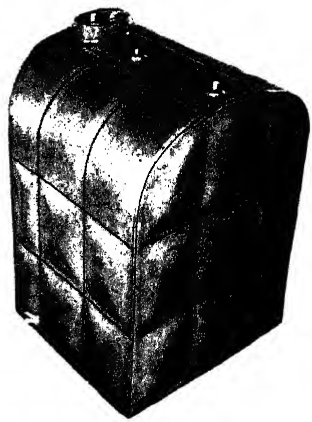


ALUMINUM TANK
IN NEED OF REPAIRS
Note baffles with lightening holes flanged for stiffness



BOLTED FITTING

FIG. V



Further information on gas and oil systems will be found in the section of this book devoted to powerplants, and instructions in regard to soldering are contained in the pages immediately following this one.

SOLDERING

Soldering is a means of insuring a positive bond between metals that have been joined, usually wires or sheets. The airplane mechanic uses this process to make low resistance electrical connections, leak-proof tank seams, etc. Soldering differs from welding in that the metals are joined, or bonded, together with a dissimilar metal, the melting point of which is lower than that of the metals being joined. This bonding metal is known as solder.

Solder is an alloy of tin and lead and has a melting point lower than either of its components. Though some types of solder contain small percentages of other metals, nearly all solder which is used by the airplane mechanic is that which is known as "50-50", composed of 50% tin and 50% lead by weight. Solder is a relatively soft alloy and for this reason a soldered bond should never be used to resist a major load.

Heat is provided for soldering either by a torch or through a soldering bit. The torch is employed on large work where the area of the seam or joint is large and where the beauty of the finish is not important. Only rarely will the airplane mechanic be called upon to do this type of work, and for this reason torch soldering will not be discussed here. The soldering bit may be heated either by direct flame or by an electrical resistance. In the former method a gasoline blow torch is frequently used to supply the flame, although blow pots, charcoal ovens, and welding torches are equally effective.

Fig. I

THE BLOW TORCH

Fig. I shows a common type of gasoline blow torch. The tank is filled about two-thirds full of clean, unleaded gasoline. The pump is operated until sufficient air pressure is built up in the tank to cause the gasoline to flow when the valve is opened slightly. The torch being cold, the gasoline comes out in liquid form, and drips into the priming pan. Note: The palm of the hand may be held over the end of the nozzle to direct the stream of gasoline into the drip pan. When the pan is partially full, the valve is closed, and the gasoline in the pan lighted. The flame from the burning gasoline heats the perforated nozzle. When the nozzle is hot, the valve is opened slightly,

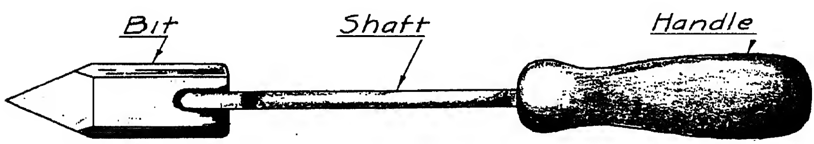


FIG. II

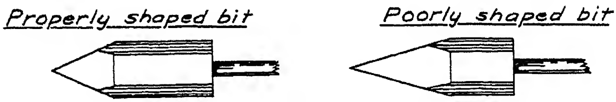
SOLDERING
(continued)

allowing the gasoline vapor which has been formed, to flow from the nozzle. When this vapor is ignited it burns with an almost colorless flame.

SOLDERING COPPERS

The soldering copper or "iron", as it is often called, is composed of three parts, the bit, the shaft and the handle, as shown in Fig. II. The bit is made of copper and is shaped so as to provide suitable working faces. The shaft is usually of iron and the handle of wood. No metal ferrules or wire wrappings are used on the handle, as they might become heated and injure the hands.

The purpose of the bit is to retain and transmit heat. If the bit is thin and sharp it will cool too rapidly. Fig. III-A shows a properly shaped soldering bit. An incorrectly shaped iron is shown in Fig. III-B.



A FIG. III B

Fig. IV shows one type of electrically heated soldering copper. Coppers of this type are excellent for doing light work where only a small but a constant amount of heat is needed. The electric soldering copper is exceptionally well adapted to the soldering of wires.

TINNING THE COPPER

A new soldering copper cannot be used successfully until after the working faces have been tinned, or coated with solder. This is due to the fact that heat causes copper to oxidize, forming a coating on the surface which will not allow proper heat transference. The bit may be tinned by heating it to a cherry red and rubbing the working faces over a block of sal-ammoniac. After the faces have become coated with melted sal-ammoniac, a small quantity of solder should be applied. The solder will adhere to the working faces and the copper will be correctly tinned. Caution: The sal-ammoniac fumes, which will rise in white clouds when the hot copper is applied to the block, should not be breathed.

Fig. IV

Soldering bits which have become "burned" or misshapen should be reconditioned before using. If the bit is incorrectly shaped it should be heated and forged into the correct shape with a hammer. Care should be taken not to hammer too long in one spot, or the copper may crack. After the correct shape has been obtained, the working surfaces should be smoothed with a file and then tinned, as

SOLDERING
(continued)

described above

If the soldering bit is correctly shaped but still does not seem to transmit heat properly, there may be a coating of oxidation on the working surfaces. If such is the case the copper should be heated and, while still hot, the old solder should be filed from the working faces. Note: This procedure should be used only to remove the oxidation. A bit should be shaped only by forging. Precautions should be taken when filing a hot soldering bit to avoid burns and also to avoid raising the temperature of the file to a point where the temper may be destroyed.

FLUX

Solder will stick only to clean metal, therefore it is necessary to scrape or sandpaper the parts to be joined until they are bright. Even then there is likely to be a small quantity of dirt on the metal and the application of heat will produce oxides which will prevent the solder from adhering. To eliminate this difficulty a flux is used.

ACID FLUX

One of the most popular types of flux that is used for soldering is muriatic acid which has been "cut" with pure zinc. Muriatic acid can be purchased from almost any drugstore. It should be kept in tightly closed bottle and plainly marked "ACID - POISON." To cut the acid for use, a small quantity may be placed in an open neck bottle or glass. Pure zinc, such as can be found in the exterior cover of an old dry cell, should be cut into small pieces and added slowly to the acid. Bubbles will be formed immediately, but the acid will not be ready for use until the bubbling ceases. The flux may be used in this state, but a better flux will be obtained by adding slightly less than 50% of distilled water and a few drops of spirits of camphor and then straining through cheese cloth to remove sediment. Caution: Exceeding care should be taken to avoid spilling the acid on the hands or clothing. If such an accident does occur, the parts should be flooded with water immediately. Acid flux should never be used to clean electrical wires, control cables, or any other small work, as the acid has a tendency to continue eating, thereby weakening the part. On other parts where it is used, the parts should be washed carefully to remove as much of the residue as possible. Acid flux should always be applied with a swab and stored in a safe place, when not in use, to prevent accident.

SOLDERING PASTE

Various soldering "pastes" are made to serve as a flux. Soldering paste is, as a rule, not as strong a cleaning agent as the acid type flux but, being a paste form, it is more convenient and safer to handle. The stronger fluxes are suspended in a wax or grease and it is often believed that the presence of the wax or grease will prevent any corrosive action from the flux. This is not strictly true and for this reason the ordinary soldering pastes should not be used for delicate electrical connections, etc. Even though soldering

SOLDERING
(continued)

pastes are termed non-corrosive, the completed bond should be thoroughly washed with water.

ROSIN

Rosin can be used quite effectively for a solering flux with little fear of harmful corrosive effects. It is widely used in the soldering of wires and radio connections. To aid in the use of rosin flux, several manufacturers have made a hollow wire solder that contains a rosin core.

SOLDERING PROCEDURE

Joining two metals by soldering can be a comparatively simple procedure if the correct methods are used. To obtain the best results the metals to be joined should be thoroughly cleaned and prepared for soldering with a suitable flux. A correctly tinned bit should be heated in a blue flame, as a red flame will "smoke" the bit or cause a deposit of soot to form on the working faces. The bit selected should be as large as can be handled conveniently, for a large bit retains heat longer than a small one, thereby eliminating the necessity of frequent reheating. If a large amount of work is to be done, two soldering coppers should be used alternately so that the metals being soldered will not have a chance to cool while one copper is being reheated.

It is possible to overheat a copper. A bit that is too hot will cause the solder to sputter and the excessive heat will cause rapid oxidation, quickly rendering the bit unfit for use. A bit should never be heated to the point where it displays changeable "peacock" colors, but on the other hand it must be hot enough to melt solder readily. The practice of holding a heated bit close to the face in order to determine the amount of heat should be avoided, for a slip or someone accidentally bumping the elbow may result in a severe burn. Note: If any part of the flesh is accidentally burned, the wound should be treated immediately. If it is a first degree burn, in which the skin is only reddened, any good burn ointment may be applied and gently bandaged into place. For more severe burns the best treatment is to apply sterile gauze which has been soaked in a slightly warm baking soda solution. The water used for the solution should be boiled to prevent infection of the burn. A solution of epsom salts may be used in a like manner. If picric acid gauze is available, it may be used satisfactorily for an emergency dressing. The picric acid gauze should be moistened in warm water and applied several layers thick and then bandaged into place. Caution: NEVER APPLY IODINE TO A BURN.

Most electrical soldering irons are automatically regulated so that they will not overheat, however they should not be left connected for a long period of time when not in use. Even if the iron does not overheat there is the possibility of its burning out or causing a short circuit which may result in a fire.

SOLDERING
(continued)

SOLDERING WIRES

When soldering wires or electrical cables, it must be remembered that the joint must first be mechanically secure. Connections are stronger after soldering but the solder should not be depended upon for the entire strength of the joint. All insulation, laquer, dirt, etc. should be removed from the wires before the joint is made.

After the cable or wire joint has been prepared, a correctly tinned and heated bit should be held against the joint long enough to raise the temperature of the wires. At this point a little rosin core wire solder may be touched to the bit or the wires. If there is sufficient heat the solder will quickly melt and flow through every portion of the joint. If the bit is not hot enough the solder will melt slowly and form a rough coating around the joint. Solder which has been put on "cold" will not make a firm bond. To correct a condition of this type the bit should be reheated and the solder melted so that it will flow through the joint. It is not necessary to use an excessive amount of solder to make a firm joint. A little solder, thoroughly melted, will cover a considerable surface if that surface is clean and the proper flux is used.

If the splice or joint is to be soldered at the bench it should be supported by a piece of scrap wood to avoid charring the bench. Wood is preferable to metal as a backing, for metal tends to draw the heat away from the joint.

Where several soldered joints are to be made at the same time it is sometimes more convenient to improvise a clamp to hold the soldering copper, as shown in Fig. I. This leaves both hands free for handling the cable and the solder. If a blow torch is used the bit may be reheated when necessary without removing it from the clamp.

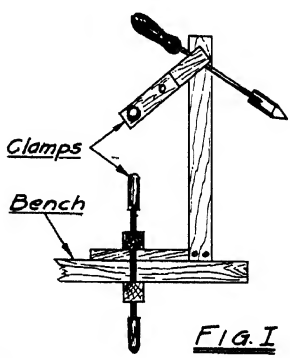


FIG. I

SOLDERING SEAMS

In general, the procedure used in soldering wires is followed when soldering seams or flat material. However, there are a few additional suggestions that should be considered. Materials to be joined should be scraped or sanded clean and a suitable flux applied. Both surfaces should be tinned, or covered with a thin coating of solder. To tin the metal the heated bit is held on the surface long enough to heat the area sufficiently so that when solder is applied to the bit it will flow from the bit to the surface of the metal and spread smoothly and evenly. If any difficulty is encountered in tinning the metal it is probably due to improper heat, dirty material, or to an untinned bit. The tinned surfaces should be placed together and the heated bit held on the outside of the joint. (Note: The heat transference will be quicker if the bit is held on the material with

SOLDERING
(continued)

a firm, steady pressure and moved along the seam slowly.) When the metals become sufficiently heated the solder on the tinned surfaces will melt and flow together, thus assuring a thoroughly bonded, or sweated, joint.

After a little practice, seams which are in a vertical position can be soldered. However, if it is possible to place the material so that the seam or joint to be soldered is horizontal, less difficulty will be encountered in the soldering job. If the work must be held in a vise it should be insulated from the vise jaws by wood blocks to prevent rapid heat dissipation.

SOLDERING HINTS

Any material being soldered should be held, or preferably clamped, firmly. Any shifting of the parts just as the solder is solidifying will produce internal fractures in the bond. These fractures are all the more dangerous because they are not readily discernible.

If any soldering is to be done on a tank that once held gasoline or other combustible substance, all open flames must be kept away from the tank. Make sure that the tank itself is well vented. If possible, the tank should be filled, or at least rinsed, with a good fire extinguishing fluid such as carbon-tetrachloride.

If a large amount of soldering must be done in a confined space, some means of forced ventilation should be employed. Very often an electric fan may be used for this purpose, but care must be taken to see that the air blast does not fall directly on the work as the solder will be cooled too rapidly.

A conveniently located fire extinguisher should be a part of the equipment for <u>every</u> soldering job.

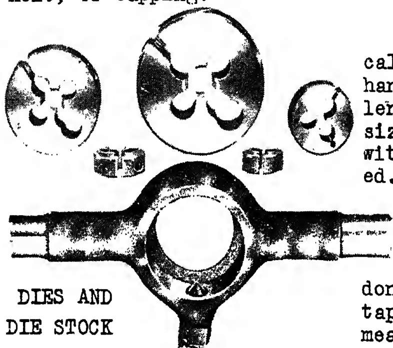
If any soldering is to be done on or near the electrical cables which are installed in the airplane, the battery should first be disconnected.

If a small soldering job is to be done on a heavy object, considerable time will be saved if the object is first preheated with the torch.

Each time a bit is heated, oxides are formed on its surfaces. For best results these oxides should be removed after each heating. One of the most convenient methods for cleaning the bit is to dip the bit into a liquid cleaning solution <u>each</u> time it is removed from the flame. A very satisfactory "dip <u>solution</u>" can be made by adding 2 pounds of melted sal-ammoniac to one quart of distilled water. In preparing this solution care should be taken not to breath the sal-ammoniac fumes. The entire bit should not be dipped into the solution, but only the working surfaces. Care should be taken to prevent the solution from sputtering on the hands or clothing.

THREADS AND THREAD CUTTING

The mechanic often has occasion to cut threads on bolts or studs and on the inside of holes. The first operation is outside threading and the second is inside threading or "tapping." There is no word for outside threading which corresponds to the word tapping, so, for purposes of distinction in the following instructions, the process of cutting an external thread on a bar or rod will be called "threading", as against cutting a thread on the inside of a hole, or tapping.

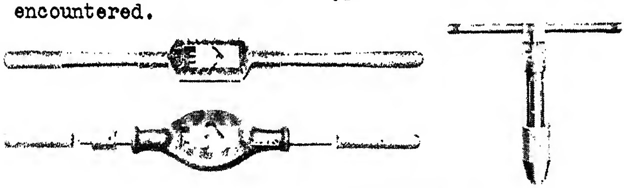


DIES AND DIE STOCK

Courtesy Greenfield Tap & Die Co.

Threading is done with a tool called a "die", usually held in a handle called a "stock." The length of the stock varies with the size of the die, which in turn varies with the size of the rod to be threaded.

Tapping derives its name from the tool with which it is done, called a "tap." The tap is held and turned by means of a tap wrench, or in the case of small taps, a tap wrench and chuck. There are many varying forms of taps and dies, but the variations, as a rule, are slight and those illustrated are typical of the styles usually encountered.



TAP WRENCHES

TAP

Tap & Die Co.

The tap shown above is the most common type and is known as a plug tap. The taper tap is made tapering, as the name implies, to facilitate starting it in the work. The bottoming tap has no bevel or imperfect threads on the end as the plug tap illustrated, but carries full threads clear to the end, and is used for finishing threads full size to the bottom of a hole.

In production work, tapping and threading are usually done on machines but the field or service mechanic must perform these operations by hand.

THREADS

A thread is simply a helical groove. The American or National thread is V-shaped, as in Fig. I-(a). The Acme thread is shown in (b), and the square thread in (c). Acme or square threads are found on screws which are regularly used for the transmission of power or

THREADS AND THREAD CUTTING
(continued)

movement. Examples will be found in stabilizer adjusting screws, landing gear hoists and similar mechanisms. Aircraft bolts and machine screws use the National form of thread.

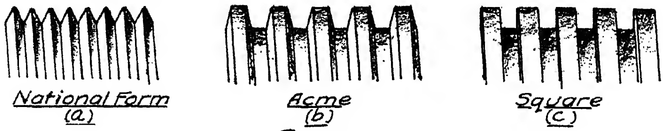


FIG. I

There are a number of special terms which apply to threads. The mechanic should be familiar with these. A right-hand thread - the usual type - is one in which clockwise rotation of the threaded part causes it to move away from the observer. Usually this means tightening the bolt or nut. A left-hand thread is one in which counter-clockwise rotation causes the part to move away from the observer. The pitch of a thread is the distance, measured parallel to the axis of the screw, between the centers of two adjacent threads. See Fig. II. Pitch is usually indicated by stating the number of threads per inch. The lead is the distance the screw travels in one complete revolution. The lead and the pitch are the same in the case of a single-threaded screw. A single thread is formed by cutting one continuous helical groove around the object being threaded. See Fig. II. A double thread is formed by cutting two parallel grooves, a triple thread by cutting three, and so on. The lead of a double thread is twice the pitch and the lead of a triple thread is three times the pitch. The root diameter of a threaded part is the diameter at the bottom of the thread. The depth of the thread is the distance, at 90° to the axis of the screw, from the outside, or top of the thread, to the bottom. The depth of the National thread may be found from the formula $d = .6495/n$, where d is the depth and n is the number of threads per inch. These terms are illustrated in Fig. II.

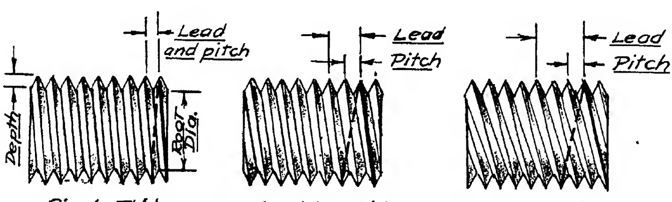


FIG. II

The National series is divided into three main groups, the coarse, the fine, and the extra-fine. National coarse threads (N.C.) formerly called U.S. Standard, are used in aircraft only where parts are screwed into aluminum or other soft material. National fine threads (N.F.), formerly called S.A.E., are used for aircraft bolts and the majority of other threaded parts. National extra fine threads are used where the thickness of the metal is low, as in the

THREADS AND THREAD CUTTING
(continued)

case of tubing. The smallest aircraft bolt is the No. 10, which is approximately 3/16" in diameter. Sizes below this are called machine screws and have been previously mentioned. The table below shows the number of threads per inch on bolts with N.F. thread, and on those with the N.C. thread.

Dia.	No. 10	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1
N.F.	32	28	24	24	20	20	18	18	16	14	14
N.C.	28	20	18	16	14	13	12	11	10	9	8

Threads of the N.F. series are made with various fits, grouped into four classes: class 1, loose fit; class 2, free fit; class 3, medium fit; class 4, close fit. Which fit should be used depends upon the type of service. The size of the tap drill determines the fit to a large extent. Most aircraft parts use the class 3, medium fit. The drill size for this fit, if no table is available, may be determined from the formula: Drill diameter = D - 1.0262/n, where D is the outside diameter of the bolt or screw and n the number of threads per inch. For example, find the drill size for a 3/8 - 24 tap.

$$D = 3/8 = .375; \; n = 24$$

$$.375 - \frac{1.0262}{24}$$

$$.375 - .0428 = .3322$$

Thus, a "Q" drill, with a diameter of .3320" is the size to use. On the second page following this will be found a table giving the sizes of tap drills. This eliminates the necessity of calculation. However, tables are not always available and for this reason it is well to memorize the formula.

It is customary to specify on drawings of threaded parts the diameter of the threaded portion, the number of threads per inch, the series (National Coarse, Nationa. Fine, Acme, Square, etc.), and sometimes the class of fit. For example, the thread on a 5/8" rod using the NF series and a class 3 fit would be specified in this manner. "5/8 - 18 - NF - 3". If the thread were left-hand, the letters LH would be added immediately after the number of threads per inch, as: "5/8 - 18 - LH - NF - 3".

Briggs, or National Taper pipe threads are discussed in more detail in the following pages. Their form is the same as the untapered National and the table below gives the number of threads per inch for various pipe sizes.

Pipe Size	1/8	1/4	3/8	1/2	3/4	1
Threads per inch	27	18	18	14	14	11½

THREADING

Threading with a die is an operation which appears extremely simple, but unless great care is observed, the beginner will spoil many pieces by getting the thread crooked, broken, or otherwise unsatisfactory.

CUTTING THREADS
(continued)

In using a die, be sure that the proper size is selected and that the die is right side up in the stock. The bottom of the die may be distinguished, as a rule, by a slightly larger opening and less sharply defined threads. The top of the die should fit against the top shoulder in the socket of the stock. Tighten the die securely in the stock, clamp the rod to be threaded in a smooth jawed vise, or between blocks of hardwood, and if there is a burr on the end, smooth it off with a file. Put some light engine oil on the rod and set the die on the end carefully, taking great care that it is square with the rod in both directions.

In starting the die, it is usually desirable to hold the handle of the stock near the center, or even to grasp the center and the die with one hand. Once it has been started and two or three revolutions made, the rest is easy. It is desirable to reverse the direction of rotation for a quarter to a half revolution for every complete turn - that is, back the die up a little for every full revolution ahead. This knocks off the chips and will produce a much better thread if the die is not sharp. Do not press down on the die, it will cut just as fast and produce a cleaner thread if left to make its own way. Keep the piece being threaded well covered with oil. In removing the die, lift it off the piece as soon as it is disengaged from the threads for if it is allowed to spin around several times in the reverse direction after it is free it will damage the thread at the end of the bar and make it hard to start a nut on the thread.

If it is necessary to cut threads close to a shoulder, such as the head of a bolt, the procedure outlined above should be followed until the thread can be cut no further, then the die should be removed and screwed on upside down. In this way the full threads can be carried clear to the shoulder, where otherwise the last two or three threads are not fully cut.

Most dies can be adjusted to a slight extent. If it is desired to make an unusually tight fit in the nut or hole, the adjusting screw in the die may be loosened, thus preventing the die from cutting so deep. On the other hand, a loose fit between the parts being threaded may be obtained by tightening the adjusting screw.

TAPPING

The operation of tapping differs from that of threading chiefly in the fact that the threads are cut on the inside instead of the outside. The hole should be drilled in accordance with the table following. If the hole does not go through the material, as in the case of a stud, the drill should be carried at least one diameter past the point where the stud is intended to end, as shown in Fig. I.

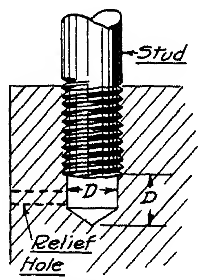


FIG. I

CUTTING THREADS
(continued)

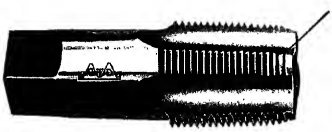
The purpose of making the hole deeper than is apparently needed is twofold. In the first place, the end of the tap does not cut a full thread unless it is specifically designed with that in view, in which case it is used only after the thread has been cut as far as possible with another tap. In the second place, chips falling to the bottom of the hole require a certain amount of space. Of course, if the piece being threaded is small enough to handle conveniently, it may be turned upside down and the chips blown out with compressed air. To aid further in cleaning out the threads, a relief hole is sometimes drilled at right angles to the hole to be tapped, smaller than the latter and meeting it at the bottom. This is indicated by the dotted lines in Fig. I.

Tap Size	Tap Drill	Drill Dia.
* 2-56	50	.0700
* 3-48	47	.0785
* 4-36	44	.0860
* 6-32	36	.1065
* 8-32	29	.1360
*10-30	22	.1570
*10-32	21	.1590
12-24	16	.1770
1/4-20	7	.2010
1/4-28	3	.2130
5/16-18	F	.2570
5/16-24	I	.2720
3/8-16	5/16	.3125
3/8-24	Q	.3320
7/16-14	U	.3680
7/16-20	25/64	.3906
1/2-13	27/64	.4219
1/2-20	29/64	.4531
9/16-12	31/64	.4844
9/16-18	33/64	.5156
5/8-11	17/32	.5312
5/8-18	37/64	.5781
3/4-10	21/32	.6562
3/4-16	11/16	.6875
7/8-9	49/64	.7656
7/8-14	13/16	.8125
1-8	7/8	.8750
1-14	15/16	.9375

Machine Screws

In the actual operation of tapping, the same procedure is followed as in threading, as regards starting the tap, using plenty of oil and backing up a half turn after every full revolution ahead.

In aircraft, the fittings for gas and oil lines, drain plugs and other parts of the "plumbing" which are threaded use the "pipe" thread. Both inside and outside threads are tapered so that when the parts are screwed together they fit as tightly as desired, thus producing a leak-proof joint. The nominal size of these threads is the diameter of the inside of commercial water pipe. A 1/4" pipe would be used in house plumbing to make threads for a water or illuminating gas pipe with an inside diameter of 1/4". In aircraft, the tubing used for fuel and oil lines is designated by the <u>outside</u> diameter of the tubing, which has a much thinner wall than ordinary water pipe. This gives rise to some confusion as a fitting with a 1/8" pipe thread would be used on copper tubing 1/8", 3/16", 1/4" or 5/16" outside diameter. The following table will clear this up. Further discussion of pipe fittings will be found in "Aircraft Engine Maintenance" (Pitman).



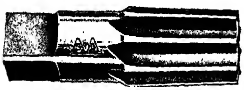
PIPE TAP

CUTTING THREADS
(continued)

Tubing Size-	1/8	3/16	1/4	5/16	3/8	1/2	5/8	3/4	7/8	1
Pipe Size-	1/8	1/8	1/8	1/8	1/4	3/8	1/2	3/4	3/4	1

The taper on most pipe threads is the American National Standard Taper, which is 3/4" in one foot. When tapping pipe threads, the hole, of course, should be tapered. The taper is made with a taper pipe reamer and care should be taken not to ream too deep, as a loose thread will result. The same thing applies to tapping. The tap should be run in until the threads are just covered, <u>and no further</u>. The procedure in tapping pipe threads is the same as with any other kind of thread. The hole before reaming should be the diameter of the small end of the reamer. The table below gives the proper drills to use.

Pipe Reamer-	1/8	1/4	3/8	1/2	3/4	1
Reamer Drill-	"0"	13/32	35/64	43/64	7/8	1-7/64
Drill Dia.-	.3160	.4062	.5469	.6719	875	1.1094

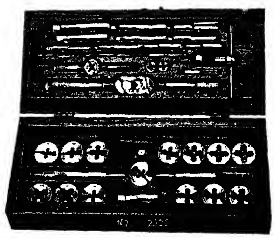


PIPE TAP REAMER

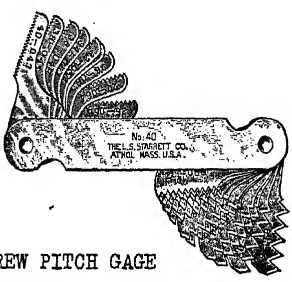
If reamers are not available, the following table gives the sizes of drills to be used without reaming wards. A less satisfactory job will result, however.

Pipe Thread-	1/8	1/4	3/8	1/2	3/4	1"
Tap Drill -	R	7/16	37/64	23/32	59/64	1-5/32
Drill Dia.-	.339	.437	.578	.719	.921	1.156

Taps and dies are usually purchased in complete sets called screw plates. One of these is illustrated. The set shown is very complete and an outfit such as this is an important part of every mechanic's tool chest.



SCREW PLATE

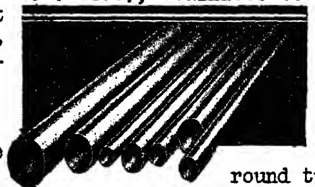


SCREW PITCH GAGE

A handy tool for the mechanic is the Screw Pitch Gage illustrated. By fitting the teeth into the threads the number of threads per inch can be immediately determined, leaving no doubt as to what tap or die to use in making a part to match.

AIRCRAFT TUBING

Aircraft tubing is made of mild steel (S.A.E. 1025), chrome-molybdenum steel (S.A.E. 4130), stainless steel, though this is not stocked by most supply houses, aluminum and duralumin. This list does not include copper tubing, which is taken up in the section devoted to power plants. It may be purchased in various shapes, round, streamline, elliptical and square, the three last mentioned being shaped from round tubing by the manufacturer.



Tubing is made, as a rule, by drawing bar stock through suitable dies, a process too lengthy to take up here in detail. When made in this manner it is known as seamless tubing. Tubing made by bending sheet stock into cylindrical shape and welding along the seam was once used for airplane construction but its use has been discontinued.

The size of round tubing is designated by two dimensions, its outside diameter and its wall thickness or gage. The sizes of shapes other than round are designated by the size of the round tubing from which they are made. While tubing can be made with a large diameter and very thin wall, it is not commonly used and accordingly is not carried in stock by manufacturer or dealer but is made up on special order. The lists below gives standard sizes of chrome-moly steel and 17ST duralumin tubing carried by one of the largest dealers in aeronautical supplies

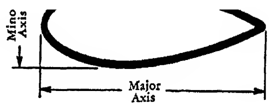
Diameter Inches	CHROME-MOLY Wall Thickness B.W.G.	DURALUMIN Wall Thickness B.W.G.
3/16	22	
1/4	22 to 16	20
5/16	22 to 14	
3/8	22 to 13	20 to 18
7/16	22 to 13	
1/2	22 to 11	20 to 16
9/16	22 to 11	
5/8	22 to 11	20 to 16
3/4	22 to 10	20 to 16
7/8	22 to 10	20 to 16
1	22 to 3/16"	20 to 16
1 1/8	22 to 3/16"	20 to 16
1 1/4	22 "	20 to 16
1 3/8	18 "	20 to 16
1 1/2	18 "	20 to 14
1 5/8	18 "	18 to 14
1 3/4	16 "	17 to 13
1 7/8	16 "	17 to 13
2	16 "	17 to 13
2 1/8	16 "	
2 1/4	16 "	16 to 11
2 3/8	16 "	
2 1/2	16 "	14 to 11
2 5/8	14 "	
2 3/4	14 "	14 to 11

AIRCRAFT TUBING
(continued)

Diameter Inches	CHROME-MOLY Wall Thickness B.W.G.	DURALUMIN Wall Thickness B.W.G.
2 7/8	14 to 3/16"	
3	13 "	13 to 11

Low carbon steel tubing has been almost entirely discontinued for aircraft use since chrome-moly costs very little more and is nearly twice as strong. In making repairs, chrome-moly should always be used instead of 1025 as then there is no doubt about the strength of the job.

Streamline tubing is designated, as stated above, by the round tubing from which it is made. The table to the right gives the standard sizes, the column under "Nominal Size" being the diameter of the tube when round.



NOMINAL SIZE In.	B.W.G. No.	MINOR AXIS In.	MAJOR AXIS In.
1	20	.571	1.349
1 1/8	18	.643	1.517
1 1/8	20	.643	1.517
1 1/4	18	.714	1.685
1 1/4	20	.714	1.685
1 3/8	18	.786	1.854
1 3/8	20	.786	1.854
1 1/2	16	.857	2.023
1 1/2	17	.857	2.023
1 1/2	18	.857	2.023
1 3/4	16	1.000	2.360
1 3/4	17	1.000	2.360
1 3/4	18	1.000	2.360
2	16	1.143	2.697
2	17	1.143	2.697
2 1/4	16	1.286	3.034
2 1/4	17	1.286	3.034
2 1/2	14	1.429	3.371
2 1/2	16	1.429	3.371
2 3/4	14	1.571	3.708
2 3/4	16	1.571	3.708
3	13	1.714	4.046
3	14	1.714	4.046

Square tubing is not used to any great extent in aircraft construction though there have been a few ships with fuselages built of square duralumin tubing bolted together through gusset plates at the joints. Due to greater cost of construction and the difficulty of designing a fuselage with all the members of approximately the same outside dimensions, this type of structure has not met with great favor.

Elliptical tubing is not very common, but is occasionally used for built-up steel wing beams or other structural parts where it is desirable to have the tubing stronger about one axis than the other. It is seldom carried in stock by dealers as the field mechanic has little occasion to use it, but it may be gotten on special order.

Duralumin tubing is often used for compression members in wings, for control push-and-pull tubes and for other structural members. Streamline dural tubes are frequently used as interplane wing struts. Aluminum tubing, due to its low relative strength is never employed for structural parts, but is often welded into aluminum gas and oil tanks for connections, and is sometimes used for the fuel and oil lines themselves.

ATTACHMENTS TO TUBING

There are a number of methods in common use of making attachments to tubing, either at the ends or elsewhere. The illustrations are largely self-explanatory. Dimensions vary, of course, depending on the size of the tubing. Fig. I illustrates a standard tube clamp, once known as the "Fokker" clamp and still referred to as such. This clamp may be made up as shown, with small tubes welded to a larger split tube or it may be purchased from aeronautical supply houses. It may be made any length by adding more small tubes as shown in "B", lugs may be welded on, as indicated by the dotted lines, or it may be made in two parts as shown in C. For clamping onto tubes up to 1/2" dia. it is usually made from 20 ga. tubing 1/16" larger in diameter than the tube on which it is to be clamped.

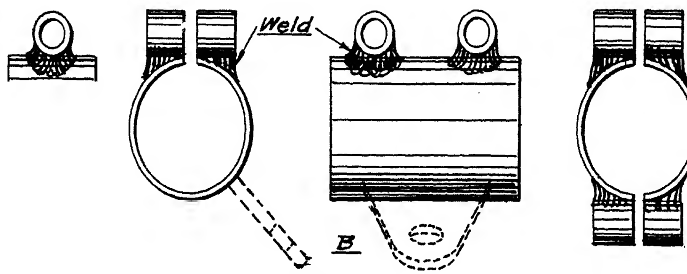
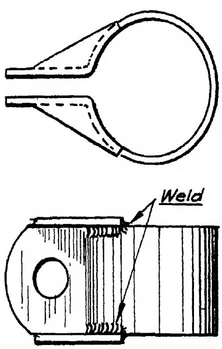
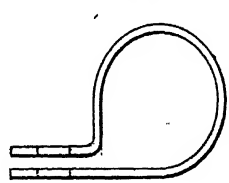


FIG. I

For fitting larger tubes, the clamp is usually made of 17 ga. tubing 1/8" greater in diameter than the tube to which it is to be clamped. The small tubes should be welded on before the large one is split.

Another style of clamp is shown in Fig. II. This is made of sheet metal and may have reinforcing webs as in "A" or not. It may be symmetrical as in "A" or offset as in "B". The type shown in "B" is often used to attach engines to the engine mount ring. When so used, the flat face, of course, is in contact with the engine. Clamps of the types shown in Fig. I and Fig. II are used where it is not desirable to weld to the center portion of a tube, either because of possible weakening of the tube or because the attachment must be removable.





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ATTACHMENTS TO TUBING
(continued)

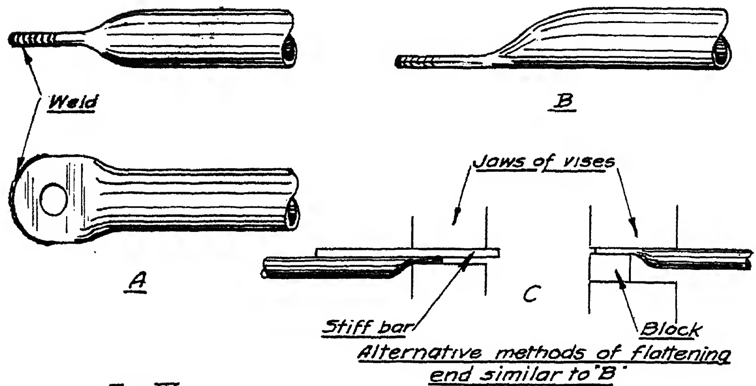


FIG. III

Fig. III shows the simplest type of tube end. The symmetrical shown in "A" is made by hammering the end of the tube flat, or squeezing flat in a smooth jawed vise, and then filing to shape. Flattening the end as shown in "B" may present some difficulties unless the proper procedure is used. "C" shows the method of making this type of end. Either "A" or "B" may be reinforced by inserting a piece of sheet stock of any thickness desired before flattening, or by welding washers on the outside.

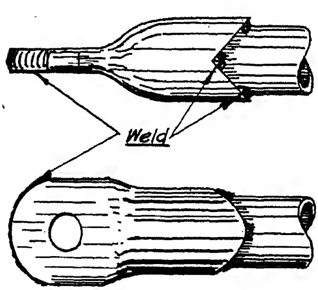
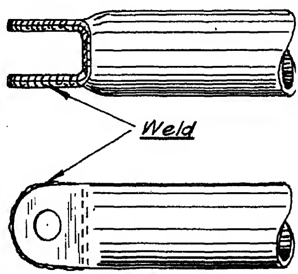


FIG. IV

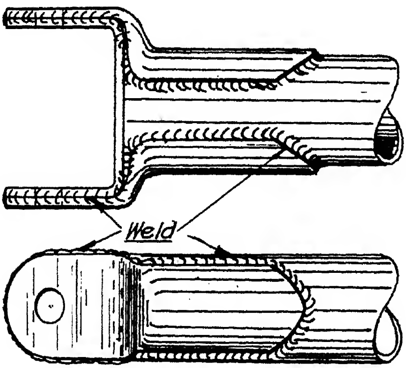
When it is desired to make the end very strong, another piece of tubing of the proper size may be slipped on before flattening. This makes an extremely strong reinforcement for either tension or compression. The outer tube may be 20 ga. and 1/16" larger in diameter or 17 ga. and 1/8" larger than the original tube.



If it is necessary to make a small yoke or fork, the method shown in Fig. V will be found satisfactory. The U piece is made from sheet stock and inserted in the end before flattening the tube. It may be found necessary to slot the tube before flattening if the

ATTACHMENTS TO TUBING
(continued)

fork is wide. A packing piece which just fits the U piece should be inserted before squeezing the tube onto it, as otherwise the U may be flattened also.



A wider type of yoke is shown in Fig. VI. This is used on control sticks, torque tubes and the like. The tube is cut off square and butt-welded to the yoke or a hole is made in the bottom of the yoke, the tube pushed through about 1/8" and welded around the edge. Reinforcing straps are welded on and while hot are shaped to fit the tube and carry across the corner as indicated.

Fig. VII shows a yoke or female end on a streamline tube. The washers and hole should be about 1/3 the larger dimension of the tube from the leading edge.

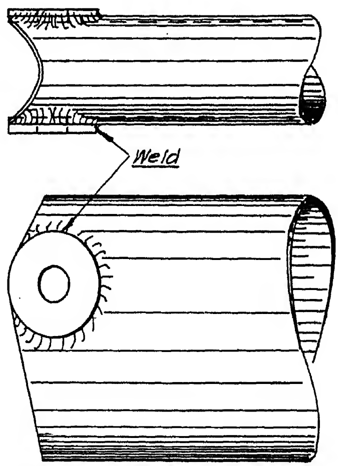


FIG. VII

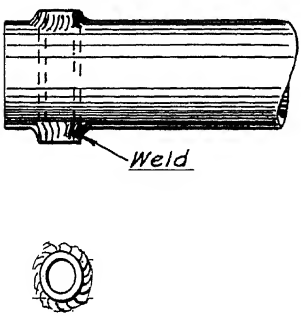


Fig. VIII is a male end which may be used on either streamline or round tubing. A small tube, of the proper inside diameter to fit the bolt or pin to be used, is inserted through a hole bored near the end of the large tube. The smaller or bearing tube extends about 1/8" on each side and is welded in place. It is good practice to have the small tube 16 ga. and 1/8" larger diameter than the bolt or pin and then ream to fit.

ATTACHMENTS TO TUBING
(continued)

It is often desirable to have tubes adjustable in length. Fig. IX shows a common type of adjustment, consisting of an internally threaded sleeve welded into the end of a tube with an eyebolt screwed into the sleeve. This may be used on one end of the tube or on both ends. If the latter, one end should have a right hand thread and the other a left hand thread. Then adjustment may be made simply by loosening the lock nuts and rotating the strut. This type of end is adaptable to either round or streamline struts. On the latter, a cover plate should be welded over the end as shown.

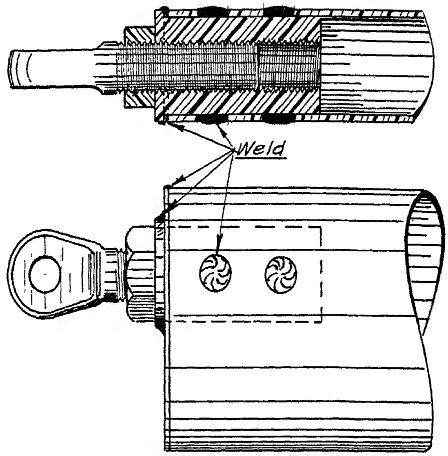


FIG. IX

If the adjustment is on only one end of the tube, it must necessarily be removed from the yoke into which it fits before any adjustment can be made. Great care should be taken not to unscrew the end too far. If there is any doubt about the length of the threaded portion the whole eye should be removed and the length checked. The screw should extend into the sleeve at least one and one-half times its diameter. The thickness of the lock nut should, of course, not be included in this measurement. Needless to say, the lock nuts should be secured firmly, particularly in those cases where there is an adjustment on each end of the strut. Even if there is only one adjustable end, the lock nut when properly tightened, prevents play between the eyebolt and the sleeve.

Struts which have open ends should be properly protected on the inside against rust and should be inspected whenever they are off to see that the protective coating is still in good condition. If the ends are closed, or if there are adjustments as shown in Fig. IX, the inside should be filled with oil and drained periodically. This is particularly true on seaplanes. Unless great care is taken it often happens that the outside of a tube is in perfect condition yet rust has eaten through from the inside until the metal is not much thicker than paper and a pointed instrument can easily be shoved right through the wall of the tube. This is, of course, a serious condition, as the member looks all right during routine inspection and yet may fail in the air.

ATTACHMENTS TO TUBING
(continued)

It frequently becomes necessary, particularly in the case of aluminum alloy tubing, to attach parts by rivets instead of welding. Terminals or fittings, due to the high concentrated loads they usually carry, are almost invariably made of steel. Obviously steel cannot be welded to some other metal or composition; hence, rivets or bolts must be employed to make the joint. No problem is presented when bolts are used; it is merely necessary to observe caution in tightening them so that the tube is not crushed or distorted.

In the case of rivets, however, the situation is not so simple. If ordinary short rivets, which pass through the fitting and one side of the tube, are used, bucking the heads is likely to present problems. If the joint is made with long, "through" rivets, which extend from one side of the tube clear through to the opposite side, the rivets are likely to bend when they are headed. In addition, since the bearing strength of the material from which the tubing is made may be much less than that of the steel used in the fitting, a third problem is introduced. However, all three problems can be solved. These solutions may be used with tubing or hollow members of any cross-sectional shape - that is, round, streamline, square, etc. Round tubing is used in the illustrative sketched below.

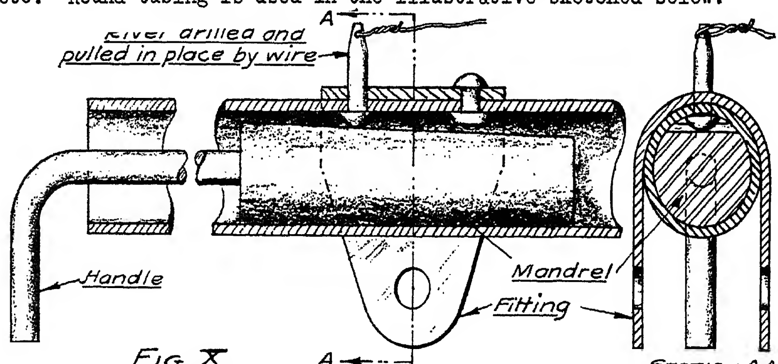


FIG. X

To buck short rivets in tubing attachments a steel mandrel may be used, as shown in Fig. X. This mandrel is made to fit the inside of the member and is then filed flat, on a slight taper, on one side. Enough material should be filed off to permit the mandrel to slide under the head of the rivet, which should preferably be on the inside of the member. If it is impossible to insert the rivet with the head on the inside, it may be driven from the outside, against the mandrel, as previously discussed under "Riveting." However, it is often possible to insert rivets in seemingly inaccessible places by a simple trick. A rivet with a shank about 1/4" too long is used. A small hole is drilled through the end of the shank, which is then filed to a conical point. A fine wire is then fed through the rivet hole in the tube or member, from the outside, until it comes out the end of the tube. The wire is twisted through the small hole in the end of the rivet, which may then be pulled into place. The mandrel is inserted until the flat por-

ATTACHMENTS TO TUBING
(continued)

tion is tightly against the rivet head. The shank is then cut off to the proper length and the riveting completed. By this means, rivets may be inserted several feet from the end of a tube. In such cases, the mandrel should be fitted with an extension or handle, of smaller diameter, and the end of the handle bent at right angles to the flat part of the mandrel.

In using this method of riveting, the rivets which are farthest from the end in which the mandrel is inserted should be put in first. Also, a constant push should be exerted on the mandrel so as to take up any clearance caused by the flattening of the inside head of the rivet.

If through rivets are used, some means must be provided to keep them from bending. Otherwise, it may be impossible to head them satisfactorily. The customary procedure is to use a steel spacer tube, as shown in Fig. XI. The inside diameter of the spacer should be the same as the diameter of the rivet. The wall thickness of the tube varies with its length. Where this is less than 2", a wall thickness of 1/32, or 20 ga., is usually satisfactory. In no case should the tube be plugged with wood to keep the rivets straight, as wood collects moisture, holds it against the metal, and produces corrosion.

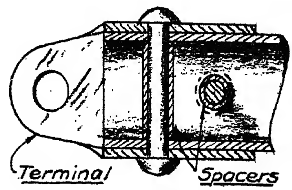


FIG. XI

One of the most satisfactory means for attaching parts to tubing is the hollow "home-made" rivet shown in Fig. XII. This rivet is particularly desirable where the bearing strength of either the tube or the fitting is low. It is made from tubing with a rather heavy wall. The material of the tubular rivet should, as a rule, be as hard as the hardest of the parts through which it passes. In other words, if the terminal or fitting is of steel, the rivet should also be of steel even if the structural member is aluminum. A wall thickness of 1/16", or 16 ga., is satisfactory where the diameter of the tubular rivet is not more than 1/2". In larger diameters the wall thickness should be increased.

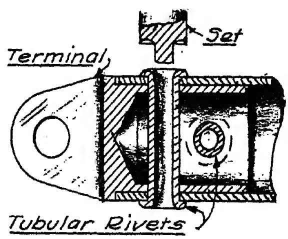


FIG. XII

The ends of tubular rivets are expanded and rolled down by means of the special rivet set shown in Fig. XII. The set should be rotated as its end is struck, and the blows should be light. Care should be taken not to split the end of the rivet, for the appearance will be spoiled by cracks even though the strength is not greatly impaired.

BENDING TUBING

The instructions below apply particularly to steel, aluminum and aluminum alloy tubing. The bending of copper tubing for gas and oil lines is taken up in "Aircraft Engine Maintenance" (Pitman).

It is quite difficult to bend tubing around a radius of less than six times its diameter. Even with the radius this large, great care is required to prevent buckling on the inside of the bend and flattening on the outside. See Fig. II - B. Unless the bend to be made is very gentle, a bending form, preferably of hard wood, similar to that shown in Fig. I should be made. If only one piece is to be bent, and if the radius of bend is fairly large, it may not be necessary to groove the form. A more satisfactory job will result, however, if the form is grooved. The bottom of the groove should be smooth and should fit the tubing accurately. The next step is to drive a tight fitting wooden plug into one end of the tube, which should be sufficiently long to extend far enough beyond the form to hold it satisfactorily. Then fill the tube with sifted sand, rapping it sharply with a block of wood as the sand is being poured in so that there will be no empty spaces left. When the sand has filled the tube and been well packed down, the open end should be plugged and the tube heated with a torch. If the material is steel, bring it to a bright red. If aluminum or duralumin is being bent, it should be heated until it will char paper. Aluminum does not change its color when heated, and will melt without even losing its silvery luster. When the tube has been heated to the proper degree, an assistant holds one end while the other is pulled around the form. Fig. II shows a tube which has been properly bent (A), and one which either was not heated properly or in which the sand was not packed tight (B). The thinner the gage of the tube, the harder it will be to bend without buckling.

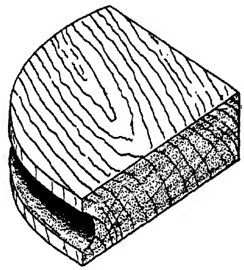


FIG. I

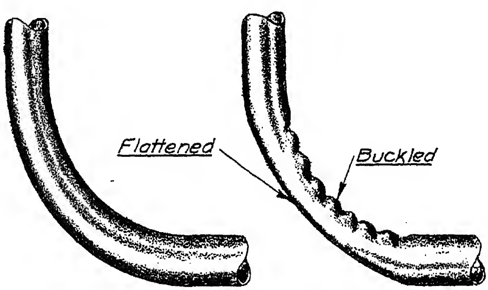


FIG. II

When a number of circles are to be bent, it is more satisfactory to make the form several inches thick and wrap the tubing around it in a spiral. One cut is then made down through the spiral and a number of rings are turned out at once. The ends of these are pulled into line and welded. In production, the form is usually made of cast iron, as the wood burns away after a time.

WELDING

Welding is a method of adding to metal parts, or fastening them together. It is used in some form on every airplane built today. In many airplanes the entire structure is fastened by welding. The fuselage, tail sections, wing ribs and beams, landing gear, etc. are often made of metal and fastened entirely by welding. In structures like these, it can readily be seen that the very strength of the airplane depends upon the strength of the weld. Welding of this type should be done only by an expert welder, having wide experience on aircraft materials.

Airplane welding is a specialized work of which every airplane mechanic cannot be expected to be master, however every good mechanic should know how to use welding equipment safely and correctly for heating, tacking, etc. Every good mechanic should understand how welding is done and the safety precautions involved. He should know what to look for in a weld and the requirements of fitting material to be welded. It is with this in mind that the following pages are written.

There are two major types of welding; electrical welding and gas welding. Electrical welding embraces arc, spot, shot, poke welding, etc. As the various forms of electric welding are usually confined to the factory and to the factory-trained workman, it will not be discussed under this head. Of the gas welding, the two main forms are the oxygen-acetylene welding and the hydrogen-oxygen welding. The hydrogen-oxygen welding is usually limited to aluminum, as the flame produced has a lower temperature than does the oxy-acetylene flame. As the oxy-acetylene welding is the most universal form of welding done by the mechanic, this discussion will be devoted to that type only.

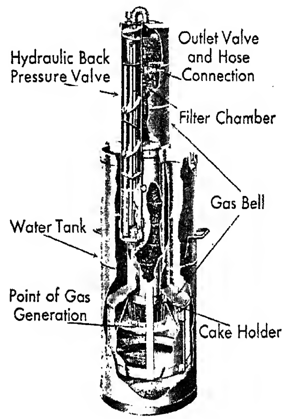
The pictures illustrating the various parts of welding outfits were furnished through the courtesy of The Linde Air Products Co. of New York City.

Fig. 1 Oxweld Welding and Cutting Unit ready for use..

Fig. I

Oxy-acetylene welding is done by raising the temperature of metals to their melting point, where they can be added to, or run together. This is done with a flame which is a mixture of two gases, oxygen and acetylene, whicn, when mixed in the correct proportions and burned, gives the highest flame temperature known to science.

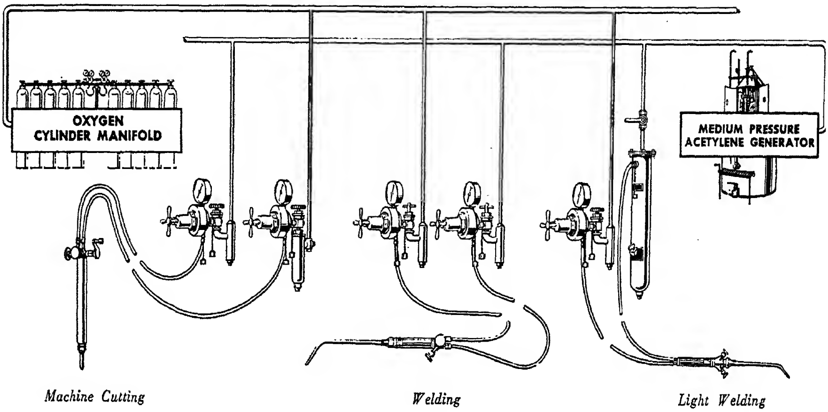
The equipment used in welding consists of four major parts; the



Construction of Portable Low Pressure Acetylene Generator.

Fig. II

WELDING
(continued)



Oxygen and Medium Pressure Acetylene Distribution System, Showing a Variety of Possible Station Arrangements

Fig. III

source of the gases, regulating devices to govern the flow of these gases, separate lines to allow these gases to flow to the fourth major part, which is the blowpipe. The blowpipe is commonly called a torch.

Probably the most convenient source of gases, especially where only a small amount of work is being done, is the oxygen and acetylene cylinders. Oxygen is always supplied in tanks or cylinders, although where a great amount is being used, several cylinders are connected to one central manifold from which many torches can be supplied. In factories and large welding stations, an acetylene generator, Fig. II, is used as a source of supply. Fig. III shows a typical factory installation.

OXYGEN CYLINDERS

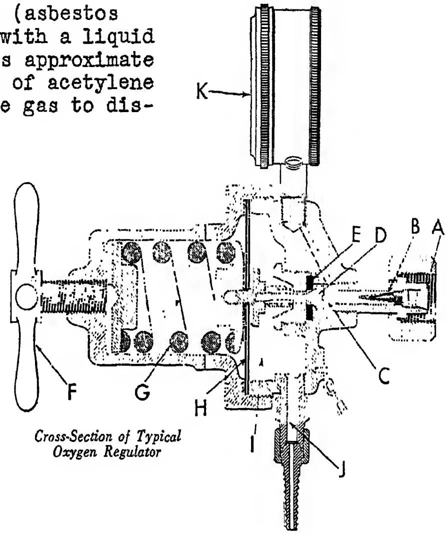
Oxygen is supplied in heavy, seamless steel cylinders of two common sizes. The smaller size holds 110 cu. ft. and the larger size holds 220 cu. ft. of oxygen under a pressure of 2,000 lbs. per sq. in. at 70° Fahrenheit. The pressure will increase as the temperature is raised and will decrease with lowered temperatures; however, the volume will not change.

ACETYLENE CYLINDERS

Acetylene gas is also supplied in heavy steel cylinders of two sizes, containing approximately 100 cu. ft. in the smaller size, and 300 cu. ft. in the larger cylinder. The acetylene cylinder is

WELDING
(continued)

filled with a porous substance (asbestos and charcoal mixed) saturated with a liquid solvent (acetone) which absorbs approximately thirty times its own volume of acetylene gas. This allows the acetylene gas to dissolve and remain as a liquid. When the valve is opened it is drawn off as a free gas.



Cross-Section of Typical Oxygen Regulator

Fig. IV

GAS REGULATORS

The gas regulators are attached directly to the gas cylinders. They serve to regulate the amount and pressure of gas delivered to the blowpipe and to prevent any fluctuation of the gases while the blowpipe is being used.

"Description of a Typical Regulator. - A typical Oxweld oxygen regulator having a stem type mechanism is shown in section on this page. Oxygen from the distribution line or the cylinder enters the regulator through inlet connection A, passing through the inlet screen B to the high pressure chamber C. The purpose of the screen is to keep particles out of the regulator that might lodge on or damage the valve seats. It will be noted that the valve stem D projects into the high pressure chamber C so that the high pressure of the oxygen will tend to force the valve stem against the valve seat E.

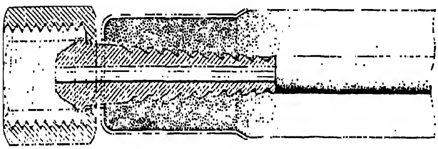
"When the adjusting screw F is screwed inward, compressing the spring G, the motion is transmitted to diaphragm H and the valve stem D. As the stem head moves away from the seat E, oxygen passes through the annular opening around the stem into the low pressure chamber I, thence through the outlet J and hose connection to the blowpipe. The gas pressure in chamber I against diaphragm H counterbalances the force of spring G, and is the delivery pressure, indicated by the delivery pressure gauge not shown in this view. Cylinder or line pressure is shown by high pressure gauge K connected to high pressure chamber C.

"Regulators for use with oxygen cylinders have rupture disks to relieve any abnormal pressure in the low pressure chamber." - from Oxweld Instruction Manual.

HOSE LINES

Hose lines are used to deliver the gases from the regulators to the blowpipe. As it is very important that these hose lines do

WELDING
(continued)



Cross-Section of Ferrule Type Oxygen Hose Connection.

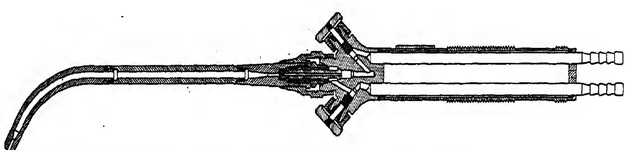
Fig. V

not become confused, standard colors have been adopted. The oxygen hose line is green, while the acetylene hose is red. Some manufacturers have the words "oxygen" and "acetylene" molded into the respective hoses at frequent intervals. To further prevent the interchanging of the hose lines, the oxygen line is equipped with connections having a right hand thread to fit a similar thread on the oxygen connection at the blowpipe and on the oxygen regulator. The acetylene connections are all equipped with a left hand thread.

BLOWPIPE

The function of the welding blowpipe is to mix the oxygen and acetylene in the correct proportions for use and to deliver the mixed gases to the tip where they are burned. There are many types of blowpipes, or torches, manufactured by many different companies, but the general principles are the same. They are made to answer a wide range of uses but as most aircraft work is rather light, a great many of the blowpipes used are of the general type shown in Fig. VI.

"The Welding Blowpipe. - A typical Oxweld low pressure welding blowpipe is illustrated in Fig. VII. At the right is the rear body which has two hose connections and the inlet needle valves, one for oxygen, the other for acetylene. Attached to the rear body is the handle of the blowpipe. Within the handle are two tubes leading from the rear body to the injector which is located in the detachable welding head. Oxygen passes through the upper tube and acetylene through the lower bringing the gases to the injector where they are mixed. The oxygen passes through the central orifice of the injector. Surrounding this orifice are a number of outlets from the acetylene tube. As oxygen passes through the relatively small opening in the injector, its velocity is increased with the result that acetylene is drawn through the relatively large side openings. Expansion of the gases in the chamber in front of the injector insures thorough mixing of the gases so that the mixture issuing from the blowpipe tip will burn properly. Changing the welding head to a different size provides a larger or smaller flame as desired." - from Oxweld Instruction Manual.

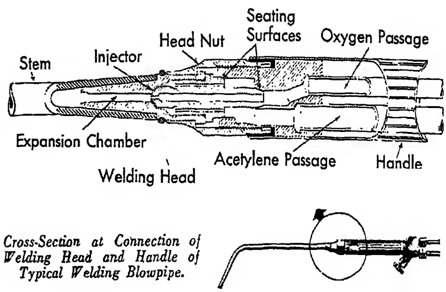


Oxweld-W-15 Aircraft Welding Blowpipe
Fig. VI

WELDING
(continued)

CUTTING BLOWPIPES

When the temperatures of iron and steel are raised to their kindling point, pure oxygen combines actively with either, to form iron oxide. This makes it possible to cut iron or steel with a jet of pure oxygen, using a series of small oxy-acetylene flames to preheat the material. By using this principle in the blowpipe and oxygen lance, it has been possible to cut through over 6 ft. of solid steel. However, for the ordinary purposes of cutting materials of 1" or 2" in thickness, a cutting torch is used, which is a combination of a blowpipe and the oxygen lance. The construction of a typical cutting blowpipe may be seen in Fig. VIII.

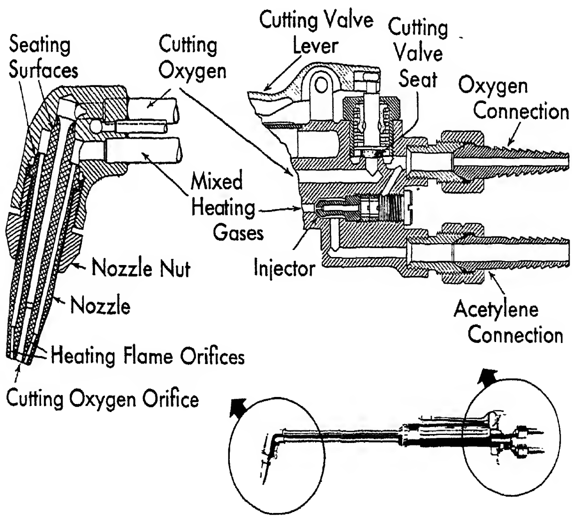


Cross-Section at Connection of Welding Head and Handle of Typical Welding Blowpipe.

Fig. VII

TIPS

Blowpipes are supplied with various size tips to suit the various jobs. In general, the heavier jobs require heavier tips.



Oxweld-C-24 Cutting Blowpipe Fig. VIII

WELDING
(continued)

SETTING UP WELDING EQUIPMENT

In setting up welding equipment the regulators should first be connected to their respective cylinders. To connect the oxygen regulator, make sure that the connections are free from any dirt or oil. CAUTION: It is imperative that NO OIL be used on or around welding equipment. Oil is violently ignited when it is allowed to come into contact with compressed oxygen. Stand to one side and crack the valve on the cylinder, letting a little oxygen blow out to clean away any possible dirt. This prevents dirt from being blown into the regulator. Close the valve immediately to avoid wasting the gas. Connect the oxygen regulator to the oxygen tank. Note: Both are right hand threads and the distinctive color is green. Tighten the nut with the wrench provided with the regulator. Loosen the pressure adjusting handle on the regulator by turning it counterclockwise, before opening the cylinder valve. This is to prevent the sudden rush or high pressure in the cylinder from damaging the gage, or its mechanism. Open the cylinder valve slowly. As this is done, the hand on the high pressure gage will move upward gradually. When the hand has stopped moving, indicating the full pressure, the cylinder valve may be opened full.

To connect the acetylene regulator to the acetylene cylinder, the procedure is much the same. Any possible dirt should be cleaned away and further cleaned by cracking the cylinder valve. The acetylene regulator and tank connections have left hand threads, and the color is red. In opening the cylinder valve, the T-handled wrench should be used. The valve should not be opened over one turn, and the wrench must be left in place, so that the tank may be turned off quickly in case of emergency.

After the regulators are attached to the cylinders, the hose lines should be connected to the regulators. CAUTION: Do not attempt to put a right hand connection on a left hand thread, as any forcing will burr the threads. After the lines are connected to their respective regulators, they should be cleaned out by letting a little gas blow through each hose, thereby removing any loose rubber or dirt. This is done to prevent any foreign particles from being blown into the torch. Caution: The free end of the acetylene hose should be held outside a window or in a well ventilated room, away from the flame. Check all connections to make sure that they are tight and leakproof. The Linde Air Products Co. recommends that a soapy water solution, using Ivory Soap, be made for testing connections. The blowpipe may now be attached to the hose lines, again making sure not to confuse the lines. The welding equipment is now ready for use.

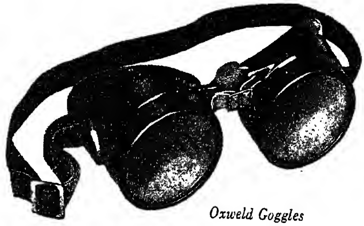
Note: It is recommended that the use of welding equipment be learned by personal instruction from a qualified welder.

OPERATING WELDING EQUIPMENT

It is impossible to give one set of directions that will prove to be the best for all types of welding equipment. Most manufacturers include an instruction book or manual, giving the methods

WELDING
(continued)

best suited for their equipment. These directions should be followed to the letter, however the general procedure is quite similar.



Oxweld Goggles

Fig. IX

Welding equipment of any type can be quite dangerous unless certain safety precautions are strictly observed. Before attempting to light a welding or cutting torch, all connections should be checked to make sure that they are in the right place and attached tightly. The cylinders are to be securely fastened to a truck or suitable cradle to keep them from falling. Cylinders should be placed where no oil is likely to drop on the gauges. It is very dangerous to weld in a small, poorly ventilated room, both from the standpoint of the harmful effects of breathing the welding gases and the possibility of the accumulation of acetylene from a small leak in the acetylene hose or connections, being ignited by the torch. Goggles of the correct shade should be worn at all times, not only to protect the eyes from the glare of the flame, but also to protect the eyes from flying sparks.

Before any welding is done, the locality should be inspected thoroughly and any inflammable material removed. When working in a shop, or near a hangar, special attention should be paid to removing any cans or buckets that may contain kerosene or gasoline. All turpentine, alcohol, paint, etc. should be put out of the way. Attention should be called to any thinner, dope, or doped fabric, as each of these is highly inflammable. These items are very easily overlooked and often prove to be the source of a costly fire. For this reason the Department of Commerce will not permit welding to be done in a hangar. Additional safety measures should include a generous supply of conveniently placed fire extinguishers.

It is not absolutely essential to wear gloves, but a good pair of gloves, preferably with soft leather faces, will save many a burned hand. Clean clothes, free from oil, may prove to be a life saver in the case of an emergency.

ADJUSTING THE REGULATORS

All safety precautions having been observed, the oxygen valve on the torch is opened a few turns, and the pressure adjusting handle on the oxygen regulator is turned in until the desired pressure is indicated on the gauge. In most cases for light work, such as heating or tacking thin material, a pressure of 10 to 15 lbs. is sufficient. Close the valve on the blowpipe.

Friction Lighter

Fig. X

WELDING
(continued)

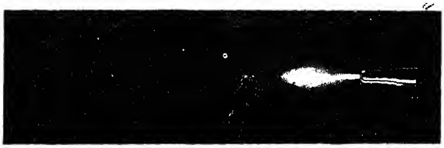
To adjust the acetylene pressure, open the acetylene valve on the torch, turn in the pressure screw on the acetylene regulator until the gauge starts to register. The pressure need not go over 4 or 5 lbs. and in no event should it go over 15 lbs. per sq. in. Close the blowpipe valve immediately to prevent the acetylene escaping.

LIGHTING THE TORCH

To light the blowpipe, open the oxygen valve slightly, turn the acetylene valve nearly wide open, and light with a flint lighter at the tip. If the flame immediately snaps out, the acetylene pressure should be increased slightly. If the flame burns a short distance away from the tip, the acetylene pressure is too great and should be reduced at the regulator.

ADJUSTING THE FLAME

With the acetylene valve on the blowpipe opened much wider than the oxygen valve, the flame will appear as in Fig. XI, or what is termed a reducing flame (an excess of acetylene). If the flame does not look like the one in Fig. XI, it may be necessary to turn the acetylene valve one way or the other to produce this effect. The flame can now be adjusted by slowly decreasing the acetylene until the acetylene envelope entirely disappears. This results in a neutral flame, Fig. XII. The acetylene must not be reduced too much, or an oxidizing flame will result, as in Fig. XIII. This will be distinguished by a slight purple or orange tinge and a shortening of the cone. The neutral flame is used for welding in all but a few special cases, such as where brass and bronze, which contain considerable lead and tin, are being welded. A highly oxidizing flame is sometimes used for this. If a neutral flame is being used it is a good practice to check the flame adjustment occasionally by turning on an excess of acetylene and then reducing back to neutral.



Reducing or Excess Acetylene Flame Fig. XI

Neutral Oxy-Acetylene Flame Fig. XII

Oxidizing Flame Fig. XIII

EXTINGUISHING THE FLAME

The torch may be shut off by simply closing both valves, how-

WELDING
(continued)

ever it is better practice to turn the acetylene valve off first.

SELECTING THE TIP

Selecting the proper tip for the job is largely a matter of experience. The nature of the work, the material, and the expertness of the welder, all must be considered before a tip with the correct size opening may be determined. A quick worker will be able to use a larger tip than a slower and less experienced man. A large tip will, of course, throw a larger flame than a small tip and consequently the metal can be heated faster, and in the hands of an expert the work can be done more quickly using the larger tip. Due to the numerous factors present in selecting a tip, no standard can be given; however, the charts in Fig. XIV will give an approximate idea of the size of tip and the oxygen pressure needed on various thicknesses of steel.

WELDING RODS

"Welding rods are drawn or cast metal rods of various diameter for various classes of work. During welding, the rods are melted into the joint. Metal from such rods forms a large proportion of the actual weld metal and consequently the rod plays a most important part in determining the quality of the finished weld.

"Good welding rods must be of correct chemical composition, and equally important, free from foreign matter or "dirt". The metal from the rod changes somewhat in its chemical composition and its properties after passing through the welding flame. A good welding

PRESSURE TABLE FOR OXWELD WELDING BLOWPIPES

Thickness of Metal		Types W-1, W-10, W-11, W-14			Types W-15, W-17, W-22		
Inches	Gauge	Size of Welding Head	Oxygen Pressure Lb. per Sq. In.		Size of Welding Head	Oxygen Pressure Lb. per Sq. In.	
			W-11,W-14	W-1,W-10		W-15	W-17,W-22
	32	0	9				
	28	1	9		1	16-24	
	25				2	16-24	
1/32	22	2	10	10	3	16-24	
1/16	16	3	10	10	4	16-24	
3/32	13	4	11	11	5	16-24	
1/8	11	5	12	12	6	16-24	10-12
3/16		6	14	14	7	16-24	13-15
1/4		7	16	16	8		13-15
3/8		8		19	9		14-16
1/2		10		21	10		16-18
5/8					11		17-19
3/4		12		25	12		19-21
1 and over		15		30	13		27-29
		20		35			
		30		45			

Note—Head sizes given are for steel, wrought iron and aluminum.
Special welding conditions may require the use of a head size larger or smaller than given.

Fig. XIV

WELDING
(continued)

rod, naturally, has its composition so fixed as to provide for these changes, so the metal in the weld will be of as good quality as parts being joined. Good rods will melt and flow freely and will readily unite with the base metal, producing sound, clean welds.

"Test For Quality. - The behavior of a welding rod in the blowpipe flame gives a good indication of its quality. It must melt quietly and easily without excessive sparking.

"Of course, the safest way is to buy rods only from a reputable manufacturer. The difference in price between the best rods obtainable and inferior rods is too small a portion of the total cost of a job to warrant the risk of failure when using the low grade rods.

"Welding rods should be stored in such a way that the different kinds of rod will not get mixed up. Steel and cast iron rods should be kept dry so they will not rust. Some manufacturers apply a very thin coating of copper or of grease to prevent rust. These coatings should not be confused with "dirt" referred to above. Dirt in the metal or on it are alike harmful.

FLUX

"Reference has already been made to the importance of selecting clean metal wherever possible for welding and of obtaining welding rods that are free from "dirt", particles of slag, or foreign matter. At welding temperatures all metals oxidize (that is, form chemical compounds with oxygen from the air) more or less rapidly and the oxides so formed act as so much "dirt". If permitted to remain in the finished weld, the oxide would seriously reduce the strength of the weld and might even make it quite useless.

"Self-fluxing Rods. - It so happens that in welding steel, oxides of the various elements form and unite together into a slag at a lower temperature than that required to melt the steel. This slag tends to float to the surface of the weld. With care on the part of the operator, these oxides can be collected on the top of the puddle of molten metal and thus removed from the joint. This action is expedited by the use of special "high test" welding rods, which contain alloying elements acting as self-cleansers.

"Use Proper Flux. - With cast iron and aluminum (in fact, with practically all of the common metals except steel) the temperature of the molten metal is considerably below the melting point of the oxides which form, so that the latter remain in the weld as solid particles. In order to get rid of this oxide a flux is used. This is a mixture of various chemicals which at welding temperatures will unite with the oxides to form an easily fusible slag.

"Since the oxides of the different metals vary widely in physical and chemical properties, no one flux is suitable for all metals. Oxweld Acetylene Company, for example, makes the following fluxes:

WELDING
(continued)

Ferro Flux	For welding cast iron
Brazo Flux	For welding brass, bronze, copper, and for bronze-welding cast iron, malleable iron and steel
Cromaloy Flux	For welding chromium alloys such as rustless irons and stainless steels
Aluminum Flux	For welding pure aluminum, aluminum alloys, and aluminum castings

"Obviously, the production of a good welding flux requires a knowledge of chemistry at high temperatures as well as experience in welding. It is a good rule to use the prepared fluxes of reputable manufacturers rather than experiment with unsatisfactory substitutes.

"Use Sparingly. - Flux should always be used sparingly. Have a little flux in a small can on the welding table and dip the tip of the hot welding rod in this as needed. Keep the can closed when not in use.

"Careless welding requires far more flux than necessary. Oxide forms most rapidly when air comes in contact with the molten metal. By holding the blowpipe so the outer envelope of the flame spreads over the weld, air can be kept away from the molten metal. The flame envelope itself is non-oxidizing when the flame is properly adjusted. The thin film of oxide that forms on the surface of the molten metal and the fused coating of slag that results when flux is properly used both act as a protection against further oxidation and should be scraped off only when they are so thick or pasty as to get trapped in the weld or to prevent heat getting to the underlying metal." - from The Oxwelder's Manual.

TYPES OF WELDING

There are two main types of Oxy-acetylene welding; fusion and bronze-welding. In the fusion type of welding the material, which is usually of thicknesses of 1/16" or less, is heated to its melting point where it can be run, or fused, together. In fusing metal of a thickness greater than 1/16", the same procedure is followed, except that as a rule, additional metal is usually required for the weld. The additional metal is supplied in the form of various diameters of welding rods. The welding rods are usually of the same material, or at least very similar to the material being welded.

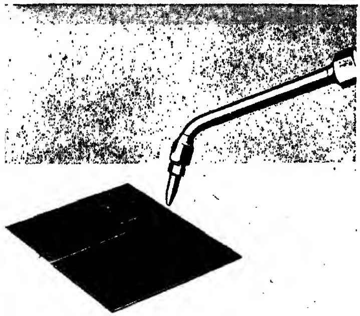
Bronze rod is used in place of welding rod in bronze welding. In this type of weld the metals are not heated to their fusing point, but are heated sufficiently to allow the melted bronze, with the aid of a flux, to adhere to the molten material. Bronze welding, commonly referred to as brazing, is usually used on heavier materials such as cast iron, wrought iron, etc. The malleability of iron is destroyed if the temperature is raised over 1300° F. For this reason, malleable iron should always be brazed.

Most aircraft welding is done on light gauge material and for this reason, the fusion type of weld is used almost exclusively. This embraces such welds as are made on fuselage tubing, aluminum tanks, monel exhaust stacks, etc.

PRACTICE WELDING

If the opportunity for the use of welding equipment presents itself, much can be learned from making a few practice welds of various types. The beginner should not attempt to do any welding unless he is assisted by an experienced welder. If this is impossible a good welding manual, such as is published by several of the large welding equipment manufacturers, should be secured and studied thoroughly.

One of the simplest types of welds and one from which much can be learned is the lap weld. To make a lap weld, secure two pieces of 1/16" steel. The pieces should be about 8" or 10" long and free from rust, grease, paint, etc. The pieces are placed on a suitable welding table so that the edges overlap approximately 5/8". The top piece must be supported so that it will lie flat on the bottom piece. After the material is ready light the torch, adjust the torch to give a neutral flame and with goggles in place, start the weld. The material is best heated by holding the torch so that the inside white cone of the flame is at right angles to the metal. The white cone itself does not touch the metal, but it should be held about 1/4 of its length above the surface being heated. If the torch is held at the right position at one end of the metal, a small puddle of molten metal will form. The puddle should be formed of equal parts of the two sheets of metal. After the puddle appears the weld should be continued across the sheet by swinging the tip with a semi-circular motion. This is done to assure the even dis-



Practice butt weld

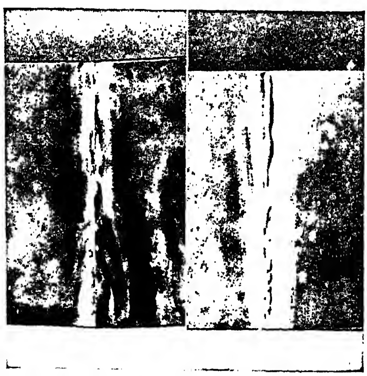
Fig. XV

WELDING
(continued)

tribution of heat on the two sheets. The torch must not be moved across the metal too rapidly or the weld will be all on the surface. Neither should it be moved too slowly, as the weld would be burned. If the torch is held too long in one spot, a hole will be burned through the metal. The motion of the torch and the speed at which it should be moved are things that can be determined by experience only. The angle of the tip to the work will also be governed largely by the shape of the material and position. However, until experience is gained a good rule to follow is to keep the tip at right angles to the material and inclined to an angle of approximately 30° in the direction of the weld. After the weld is complete and the material is sufficiently cool, place one sheet in the vise and break the weld open with a hammer. This should be done so that the effect of the weld may be seen by an inspection of the under sides. Inspect the weld and notice defects and try it again.

There are three other types of welded seams that are used considerably in aircraft work; the butt weld, the corner weld, and the flange weld. Each of these types of welding should be practiced on short lengths of material, the same as was done with the lap weld.

More complete information as to the various types of seams and welds will be found in the Oxwelder's Handbook, published by the Linde Air Products Co., New York City.



Under side of butt welds in sheet steel.
Left—Poor weld. Right—Good weld.

Fig. XVI

WELDED JOINTS IN TUBING

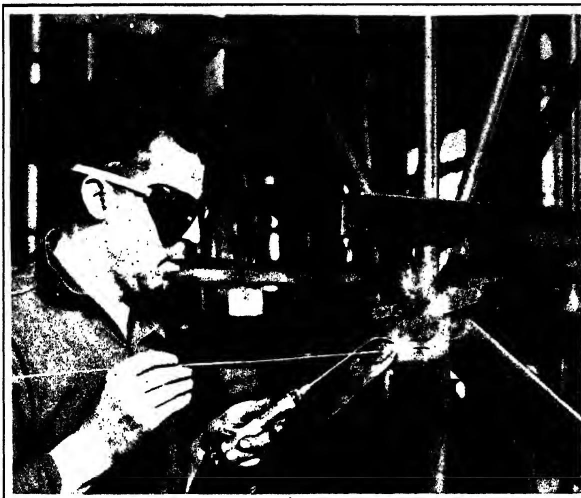
A great percentage of the airplanes of today are made with a welded steel tube fuselage. While the welding of such important structural parts as fuselage joints, etc. should be left to the aircraft welder, the mechanic is often called upon to fit the material for these welds. A "cluster joint" such as shown in Fig. I must be fitted exactly, not only to insure ease of welding, but to insure the correct positions of the tubes so that the various stresses will be transmitted correctly. Although the fuselage is built in a jig, the tubes could easily be off center or slightly eccentric unless they are carefully fitted.

In almost every case, tubing joints are fitted so that the centerlines of the tubes meet at one central point, Fig. II. This is an important point, as a dangerous load can be thrown into the joint by an eccentric tube.

Truss joints of the type shown in Fig. II are often reinforced by slotting the tubes and inserting a flat sheet of metal which is welded to all tubes, Fig. III. This is called a web reinforcement.

One of the greatest aids to fast, easy welding of tubing joints is the proper fitting of the tubes. Not only must the parts match correctly, but the correct amount of clearance must be allowed for the expansion and contraction of the metal that accompanies all welding.

If the mechanic is fitting material of any kind to be welded, it is best to first discuss the needed clearances with the welder, as he is in a position to know exactly how the metal will react to heat.

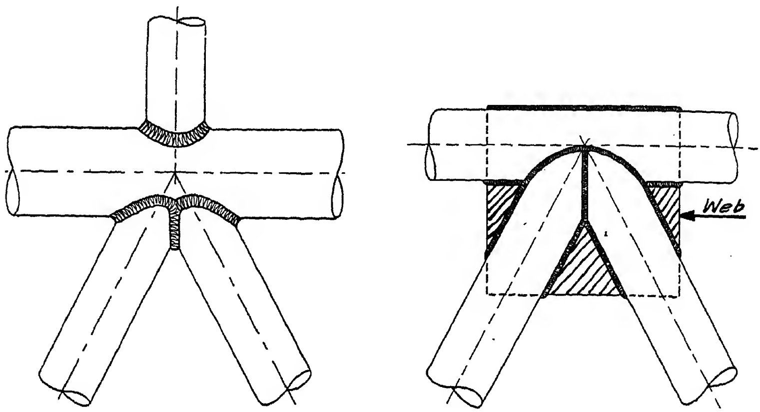


Illustrations, Courtesy of Linde Air Products Co.

ge Welding

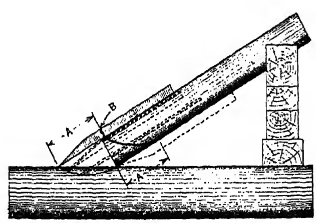
WELDED JOINTS IN TUBING
(continued)

In fitting tubing joints it is, as a general rule, desirable to have a clearance of from 1/32" to 1/16", according to the size of the tube, to allow for expansion.



The most important and also the most difficult part of fitting tubing is to scribe the correct curve layout on the tube. Tubes are often fitted by the trial and error method of simply cutting the tube longer than necessary and filing it with a round or half round file until the correct fit is found. However, much time will be saved if the method shown in Fig. IV is used. With slight variations this method can be used for many types of joints.

"Block the branch at the desired angle and position to the header. The end of the branch can be held firmly in position on the header by means of a small tack weld. Along the upper side of the branch, lay a straight edge with the end A just touching the header. Mark the straight edge at a point B, near the end of the branch and mark the branch at B also.



"Move the straight edge around the branch, keeping it parallel to the centerline of the branch and having point A touch the header at all times. Mark on the branch the various positions of B, as the straight edge is moved around the pipe. Draw a smooth curve through these points". - from The Oxwelder's Manual.

OTHER TYPES OF WELDING

Recent developments have so popularized the use of aluminum and special corrosion-resistant steel alloys for aircraft construction that many new or more efficient methods of fabrication have been developed. While many of these processes still remain in the "specialized" class, the widespread usage of welding in its various forms makes it desirable for the mechanic to familiarize himself with, at least, the basic principles of the various types in order that he may better understand his job. As has been previously stated, it is not within the scope of this book to give a complete course on welding. To the mechanic desiring such a course it is recommended that he make inquiries of the companies which are engaged in the manufacturing of the materials or of the welding equipment in question.

WELDING ALUMINUM ALLOY

The following discussion of the basic principles of flame-welding aluminum alloy sheet is reprinted by the courtesy of the Linde Air Products Co.

The physical characteristics of aluminum necessitate a welding technique just as easy, but somewhat different from the well-known steel welding procedures. Primarily, the metal's rate of heat conductivity, its color characteristics when heated, its change in physical properties when hot, and the easily formed, high melting point oxide are the factors which determine the welding procedure.

The rate of thermal conductivity is high and the point of fusion or melting point is low. This means that when heat is applied to the metal at any point, it is carried away and dispersed rapidly throughout the body of the metal.

The metal apparently remains exactly the same in form and color almost to the melting point. There is little indication by a change of color that the metal is approaching the welding heat. When the melting point is reached, the metal collapses suddenly. Actually aluminum does change in color on being heated, but the change is so slight that it is noticeable only in the dark. Under ordinary shop lighting conditions this is seldom seen.

The formation of a thick, heavy oxide on the heated and melted surface is a further factor which fundamentally determines part of the welding technique. When exposed to air, this oxide forms rapidly as a scum on the surface of the fluid metal. Furthermore, this oxide has a melting point much higher than aluminum. In order to make a sound weld, then, this slag must be removed. The method of removal is discussed at a later point.

The hot shortness of aluminum and many of its alloys is another factor that must be considered. Due care must be taken to see that aluminum parts are adequately supported when hot. The aluminum-silicon alloys are unusually free from hot shortness.

Commercial Grades of Aluminum and its Alloys - Welding consideration of aluminum and its alloys pertains largely to the grades ordinarily designated as follows: high purity, 2S, 3S, 51S, 53S, and casting grades.

OTHER TYPES OF WELDING
(continued)

The grade known as 2S is the commercially pure aluminum. This is 99 per cent pure. It is one of the easiest forms to weld.

The low manganese content alloy, 3S, usually contains about 1.25 per cent manganese with a minimum of 97 per cent aluminum. This is another of the easily welded forms.

The 2S and 3S materials come in several conditions of cold work hardness, ordinarily designated as follows: O, annealed; 1/4 H, quarter hard; 1/2 H, half hard; 3/4 H, three quarters hard; and H hard. In the case of 2S and 3S in any of the H tempers, the metal is annealed by welding. The resulting joint should then be considered as having strength on the same order as the soft temper metal, or as in the O condition. Cold hammering the joint after welding will increase the hardness temper to a degree.

The more important types of strong aluminum alloys, which depend upon heat-treatment for their strength characteristics are designated as 51S and 53S. Each of these types is available in several different modifications, according to the exact heat-treatment given during manufacture. These alloys are widely used, and can be welded satisfactorily.

The 51S alloy is a silicon-magnesium-aluminum material. This is a readily welded, heat-treated alloy of considerable strength.

The alloy 53S also containing silicon and magnesium and about 0.25 per cent chromium meets the three requirements of corrosion resistance, weldability and strength.

There is a large group of cast forms of aluminum of various compositions. Generally speaking, these can all be satisfactorily welded either in fabricating an assembly or for repair purposes.

Welding Rod - Generally speaking, the most consistently satisfactory results are obtained by the use of welding rods (Oxweld No. 23 Aluminum Rod, a silicon-aluminum alloy rod, and Oxweld No. 14 Drawn Aluminum Rod, 2S Aluminum) specially designed for welding aluminum and aluminum castings. The silicon-aluminum alloy rod is suitable for all aluminum welding except 2S and 3S, for which the drawn aluminum rod (2S) or strips cut from the same material are best. Other exceptions are certain of the heat-treated alloy castings and certain applications in which a color match may be necessary or desirable. The rod has characteristics not found in any other type of aluminum welding rod. Its use aids greatly in insuring uniformly sound welds in practically all types of work, producing very high grade weld metal.

Fundamental Welding Technique - The fundamental welding technique is practically the same for sheet, plate or castings. For this reason the basic technique features will be discussed in this section, and the peculiarities of joint design, preheating and other factors will be discussed in separate sections.

It is extremely important in the welding of aluminum that a

OTHER TYPES OF WELDING
(continued)

slightly reducing flame be used at all times. An excess oxygen flame will cause rapid formation of aluminum oxide which is detrimental to efficient welding. Too great an excess acetylene flame should also be avoided. The flame adjustment should be made so that it is of a low gas velocity and soft, not "blowy" and harsh.

A blowpipe tip or head one size larger than that ordinarily used for welding steel of the same thickness is recommended.

The use of a flux is essential for best results. Flux is necessary to remove the oxide which collects as a heavy thick skin on the surface of the weld. Aluminum flux is sold as a powder which is best applied by mixing with water to a free flowing consistency. It is then applied with a brush to the welding rod. Where no welding rod is used, as on flanged joints, the flux is painted on the flanged edges.

Flux containers, in the form of a long slender tube of aluminum, brass, or glass, are preferred by some operators. Steel cannot be used for this purpose as it contaminates the fluid. This tube is kept full of flux and water mixture and the welding rod is dipped in this before use. The mixture should be stirred frequently.

In welding heavier material the flux is applied both to the rod and to the base metal as well. By painting the seam on both sides, an ample quantity of flux will be assured.

Because of its low melting point and bright color, aluminum does not show a red heat as steel does. There is no visible indication that the metal is approaching the melting point. The surface oxide forms very rapidly on the puddle surface. As this has a melting point much higher than that of the metal, use of the flux becomes essential for most efficient welding.

When welding, the blowpipe should be held at an angle of about 30 deg. to the plane of the weld. This will avoid blowing holes through the metal when it is hot. The end of the inner cone of the flame should be held at least 1/8 in. away from the metal. Inasmuch as fusion takes place very rapidly, the blowpipe should be moved quickly along the seam. It is generally better to complete the weld in one operation. Should a section prove to be faulty and have to be replaced, ship out the old weld metal and reweld with new metal.

One of the main points in which the process differs from the more familiar steel welding is in the speed of working. As the metal ahead of the blowpipe becomes heated, the weld must be completed rapidly.

The blowpipe flame is directed so that it melts both the edges of the sheet and the end of the welding rod at the same time. Both sides of the weld must receive an equal amount of heat to produce even and smooth welds.

When starting to weld, the two edges should begin to melt before welding rod is added. The correct time to start moving along

OTHER TYPES OF WELDING
(continued)

the seam is quickly learned by the operator.

The welding rod should be held in a direct line with the weld. The tip of the rod is held in the flame near the metal. Metal from the welding rod should fuse thoroughly with the base metal as it is added. The weld can be built up above the surface of the base metal if desired.

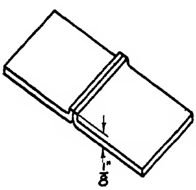
It will be noted in aluminum welding that but a small portion of the metal is molten at any one time. As soon as the flame is withdrawn the puddle solidifies. This makes possible regular ripple welds of good appearance where it is desirable to use the article without finishing.

The metal must be watched carefully for signs of melting; color, as mentioned previously, will give little indication of this. Experience will show the proper time for adding weld metal.

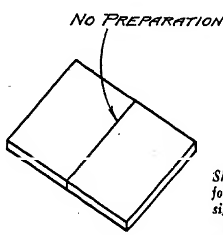
These features are fundamental to the welding of aluminum and its alloys regardless of the special consideration for the various shapes and materials.

Welding Sheet Aluminum - For the welding of sheet aluminum the first consideration is that of the joint design. Two types of joints are commonly used, and a third only occasionally. One is the butt type joint in which the ends of the pieces are placed butting against one another. The second is the flanged joint in which the edges of the two pieces, or sometimes only one of the pieces, are flanged and on which no welding rod is used. The metal in the flange is melted down to form the weld metal. The third (not as efficient as the first two mentioned) is the lap joint in which the two pieces overlap one another.

Aluminum sheet 16 gage and lighter can be flanged in preparation for welding. The flange should be about the same height as the thickness of the sheet, or possibly just a little higher. This would mean that the top of the flange to the bottom of the plate would be approximately 1/8 in. The joint is made by holding the two upstanding edges together and melting these down. For such work no welding rod is required, although it is always well to have some on hand to use, if necessary, in obtaining fusion. Flux is painted along the upstanding edges before welding begins.



Sketch showing joint preparation for flange type joint. This is suitable for thicknesses up to 16 gauge

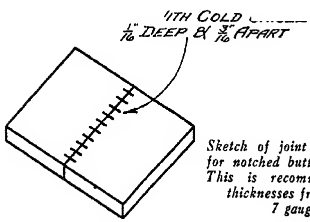


Sketch of joint preparation for butt type joint. This design can be used for thicknesses up to 17 gauge

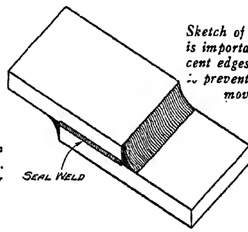
OTHER TYPES OF WELDING
(continued)

Sheet up to 17 gage can also be welded with a plain butt type weld. Beveling is unnecessary for this. Welding rod can be used if it is desirable to reinforce the weld. In some instances it can be dispensed with entirely. Here again the flux should be painted along the edges of the sheet before welding begins.

For material from 17 to 7 gage in thickness it is recommended that the edges be notched in order to facilitate complete penetration when fusion takes place. The edges of the sheet are notched through the entire thickness, the notches being approximately 1/16 in. deep and 3/16 in. apart. In welding, the notched edges are



Sketch of joint preparation for notched butt type joint. This is recommended for thicknesses from 17 to 7 gauge



Sketch of double lap type joint. It is important to seal weld the adjacent edges of the overlapping plate to prevent moisture getting to unremoved oxides and flux.

butted close together; it is then easy to get full penetration. With the help of these notches, the flux works down to the full thickness of the material and considerable welding rod is saved. There is less chance of melting holes through the sheet, and the notches also act as small expansion joints to prevent local distortion.

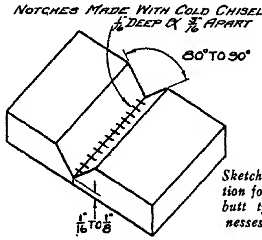
The lap type joint is not recommended unless conditions are such that no other type of joint can be used. Aside from the undesirable stress distribution factors of this type of joint, which make it less efficient than other types, there is the matter of flux removal. It is practically impossible to remove flux and oxide particles that have been left along the enclosed side of the weld in this type of joint. Inasmuch as the removal of this is almost essential to prevent subsequent corrosion of the joint, it is easily seen why this design is not recommended. Because of this factor a single lap should never be used. If it is necessary to make a lap type joint, a double lap (shown in one of the accompanying sketches) should be used. Both overlapping edges should be welded completely to the adjacent metal. Then care should be taken to seal in the ends of these types of joints so that no moisture can get in between the two pieces of metal. The remaining oxide and flux which cannot be cleaned off between the sheets will not affect the corrosion-resistant quality of the welds if no air can get into them. This is the reason it is recommended to seal in this space.

Before welding aluminum sheet it is good practice to warm up the entire sheet with the blowpipe. This takes off the "chill" and reduces the susceptibility to cracking as well as decreases the effect of expansion. In welding long seams, tack welds should be made every 3 or 4 in. If unusual distortion is encountered in spite of this, welding may be stopped and the sheet hammered out. It is not

OTHER TYPES OF WELDING
(continued)

advisable to attempt a large amount of straightening after welding is completed.

Sheet aluminum should be welded at the greatest possible speed in order to obtain the best weld metal and the least amount of distortion.



Sketch showing joint preparation for a single vee notched butt type joint. For thicknesses greater than 7 gauge

The welding flame should be held close to the work so that the inner cone almost touches the metal. This results in heating but a very small area and greatly minimizes the danger of burning through. It is almost impossible to prevent burning through on light sheet unless the flame is held very close to the work. A large portion of the flame should be directed on the rod itself as the molten pool of aluminum will not melt the rod. The welding flame should be directed at an angle of between 30 to 40 deg. to the surface of the sheet. This angle should be greatly decreased when approaching the end of the sheet. It is sometimes advisable on very thin material to start the welds inside the edge and weld toward it.

ELECTRIC WELDING

Electric welding embraces all those types of welding which utilize an electric current to produce the heat required for the fusion of the metals. The processes described below are forms of electric welding.

Arc Welding - The current for arc welding is usually supplied by a special arc welding generator. In factories this equipment is stationary, but for mobile units it is mounted in a motor truck. Two extension cables, or leads, are provided, one of which may be clamped to the metal being welded (or its metallic support); the other terminates in an electrode holder. The holders are provided with a spring arrangement so that the welding rod may be changed quickly. One type of electrode holder is shown in Fig. I.

Arc welding is accomplished by striking the material to be welded with the welding rod which is clamped in the holder. This completes an electrical circuit and produces an extremely high temperature at the point of contact. The electrode is immediately withdrawn to a distance of about 3/4" from the work, causing an arc to be formed between the electrode and the work. The exact distance between the electrode and the work depends, of course, upon the voltage being used, the type and material of the electrode, and the size of the material being welded. A welding mask, such as that shown in Fig. I, is used to protect the eyes from the extreme brightness of the arc. Arc welding should never be viewed, even momentarily, unless the eyes are suitably protected, as the blinding glare

OTHER TYPES OF WELDING
(continued)

may seriously injure the vision. The welding mask also has an extension shield to protect the face and head from flying bits of molten metal.

COURTESY ALUMINUM CO. of AMERICA

Fig. I

The arc formed between the electrode and the work quickly melts and vaporizes the tip portion of the electrode This vapor remains within the limits of the arc and moves away from the electrode toward the lower pressure area near the material. As the vapor touches the work, its temperature is lowered and consequently is deposited there in the form of molten metal. When the arc is moved away, this metal solidifies quickly.

Considerable skill is required to manipulate the electrode correctly. It must be struck against the material and immediately withdrawn a short distance. If it is allowed to remain in contact with the metal for even a short period of time it becomes permanently welded to the metal. A stuck electrode may sometimes be broken loose by a quick side-thrust of the holder; otherwise it will have to be removed with a cold chisel. The current should be shut off in the latter case. If the electrode is withdrawn too far, the arc will be lost and the entire process will have to be repeated. Holding the electrode too close may cause holes to be burned in the work. After the arc has been formed it must be moved forward so that sufficient material is deposited in the proper position and must also be moved downward (as the electrode burns away) in order to maintain a constant arc length.

There are two popular types of arc welding, the Slavianoff system and the Bernardos system. In the former, a metallic electrode in the form of a wire or rod is used in the holder. This electrode is usually connected to the positive side of the circuit. In the Bernardos system, a graphite or carbon electrode is used, usually in the negative side of the circuit. The arc formed by this electrode is used only to raise the temperature of the material to the welding point. If any additional material is required to complete the weld, it is supplied from welding rod. This process is commonly called

OTHER TYPES OF WELDING
(continued)

the "carbon arc" method, whereas the other is referred to as "metallic arc", or simply "arc" welding.

ELECTRICAL RESISTANCE WELDING

This type of welding utilizes the electrical resistance formed by the contact of two metals to produce the heat necessary to raise the temperature of the metals to their fusion point.

Butt Welding - Butt welding is often used to fasten the ends of small strips of metal, wires, rods, etc. to similar pieces. The metals to be joined are clamped so that they touch each other and a heavy low voltage current is passed through them. At the point of contact between the two metals the temperature is raised. When it reaches the fusion point a heavy pressure is exerted on the pieces of metal, forcing them together and at the same time insuring a positive bond, or fusion of the metals. The current is cut off as soon as the weld has been completed.

Flash Welding - Flash welding is similar to butt welding except that the current is sent to the two pieces of metal before they are brought into contact with each other. After the current is turned on, a light contact is made and the flash, or arc, which accompanies the contact is sufficient to fuse the metals.

Spot Welding - Spot welding is the process employed in welding sheets of metal together at small points, or spots. It is done by placing an electrode on each side of the point to be welded. Typical electrodes are shown in Fig. II. A low voltage electric current is passed through the materials at this point, immediately heating the metals. A slight pressure on the electrodes insures the complete fusion of the material. The size of the electrodes, the amount of current needed, and the length of time required to make the weld, depends upon the thickness and type of material being welded. Sheets up to 1/2" in thickness can be welded successfully in this manner.

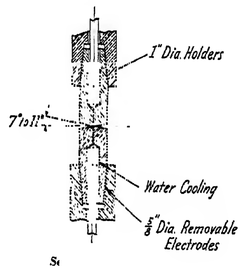


Fig. II

A spot welded joint is estimated to be about 60% stronger than a riveted joint which has been made by using rivets of the same diameter and spacing as the spot welds. Although spot welding does not have as wide a range of application as do rivets, it is more economical, for it eliminates the drilling and matching of holes and the additional weight of the heads of rivets. Furthermore, it dispenses with the necessity for flush rivets, since the spot weld does not project beyond the surface.

One type of spot welding machine is shown in Fig. III. The material to be welded is inserted between the upper and lower electrode. Pressure on a foot treadle brings the upper electrode to bear on the metal directly above the lower. As soon as sufficient pressure is exerted to insure a positive contact between the two

OTHER TYPES OF WELDING
(continued)

metals being welded, a current is automatically turned on and the weld thereby made. Machines of this type are provided with an automatic current shut off, thus insuring the uniformity of each weld.

More recent developments in the field of spot welders has produced a fully automatic machine which is capable of making a series of welds at high speed. These welds may be made to overlap if desired. Such a machine is commonly referred to as a shot welder, or seam welder. Fig. IV shows one type of seam welder. The electrodes of this machine are circular disc rolls between which the material is fed. The number of welds per minute and the rotation of the roller-electrodes can be governed to produce either a continuously welded, or an intermittently welded seam.

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Fig. III

Overlapping spot welds produce a continuously welded seam which is both air and water tight. The speed with which a seam of this type may be fabricated, together with its strength, flush surface, and reduction in weight over a riveted seam, make it particularly well suited for boat hulls, wing skins, metal control surfaces, etc. Shot welding is especially suitable for stainless steel structures where it is used in the fabrication of spars, ribs, bulkheads, etc., in addition to coverings.

Poke Welding - Poke welding is a form of spot welding in which only one electrode needs to be in direct contact with the material at the point where the weld is being made. The second electrode, or lead, is clamped to any portion of the material. Poke welding is commonly used in places where it is impossible or impractical to use

OTHER TYPES OF WELDING
(continued)

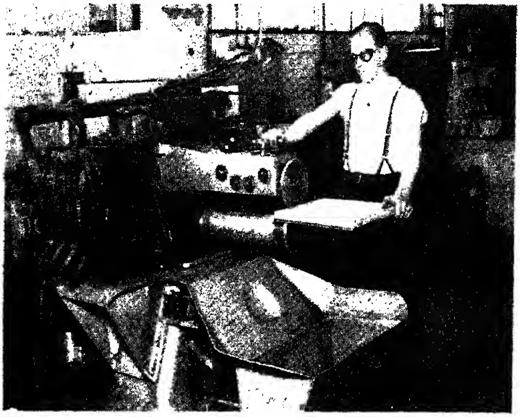

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Fig. IV

the conventional spot or seam welder. The movable electrode is operated by hand in a manner similar to a pneumatic riveter. The electrode "gun" is pressed against the spot where the weld is to be made with sufficient force to insure a mechanical contact between the two sheets of metal. Additional pressure closes a spring tension switch, after which a low voltage current acts to complete the weld. Ordinarily, the current shut-off is not controlled automatically, the effectiveness of the weld depending upon the skill and judgment of the operator.

HOW TO MAKE AN AILERON RIB

The directions given here are for making a metal tube aileron rib. It is to be fastened by welding, however if welding equipment is not available the tubes can be fitted for welding and the rib left in the jig.

MATERIAL: Chrome molybdenum steel tubing; 6 ft. of 5/16" O.D. tube; 6" of 2" O.D. tube (the tube should have a wall thickness of about .030"); material for jig base.

TOOLS: Hack saw, round file, hammer, anvil, welding equipment.

PROCEDURE:

1. Lay out the jig base for the aileron rib. Referring to the rib jig layout in the woodworking section, the trailing section of the Clark Y rib may be used to secure the camber of the aileron.

2. Make a jig for the rib so that the tubes will be held in the positions shown in Fig. I. The jig can be made with a hardwood base, although a metal base is preferable. The jig spacers should be metal pegs, located as indicated by dotted circles in Fig. I. These may be made by driving a #10 steel wood screw into the hardwood base at the correct locations. The screws should extend at least 5/16". Cut the heads from the wood screws to allow the tubes to be placed in the jig. If a metal base is used, short lengths of 3/16" rod may be welded directly to the base in the proper locations.

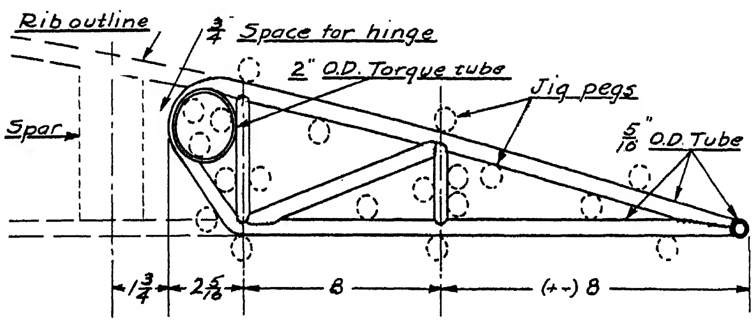


FIG. I

3. Cut a 1/2" length from the 2" tube and hold it in place with three or four pegs or studs as shown in Fig. I.

Note: The aileron rib is not to be welded to this 1/2" section of tube. The tube serves merely as a guide around which to shape the rib. This 2" tube represents the main member, or torque tube in the completed aileron.

HOW TO MAKE AN AILERON RIB
(continued)

4. A 1-1/2" section of the 5/16" tube must be flattened where the tube goes around the torque tube. Mark out this portion to be flattened, starting at a point 20" from one end of the tube.

Note: In most cases it is not desirable to attempt to flatten steel tubing while it is cold, as the tube very often splits at the edges. For small tubes sufficient heat can be obtained from a good gasoline blow torch. If welding equipment is available the welding torch should, of course, be used to heat the tube. The tube should be heated to a dull red and flattened with a hammer on the anvil.

5. Heat and bend the tube to shape and place in the jig.

6. Saw off any excess tube at the trailing end. These short lengths are to be used for the web reinforcing members.

7. Cut and file the web reinforcing pieces and place them in the jig.

Note: The upright pieces should be placed first. The diagonal piece should be so fitted that all the centerlines of the tubes meet at one point. See "Welded Joints in Tubing". These pieces should be filed to a snug fit, but should be a little short, so that a clearance of approximately 1/32" is left at each joint to allow for expansion when welding.

8. Cut and file the trailing edge joint as shown in Fig. I. This is for a 5/16" steel tube trailing edge. If a metal channel trailing edge is to be used the trailing ends of the tube should be flattened to come to a sharp point. The insides of the tube should be flattened as shown in Fig. II.

9. The rib is now ready to be tack welded. After the rib is tacked it can be removed from the jig and the welding completed.

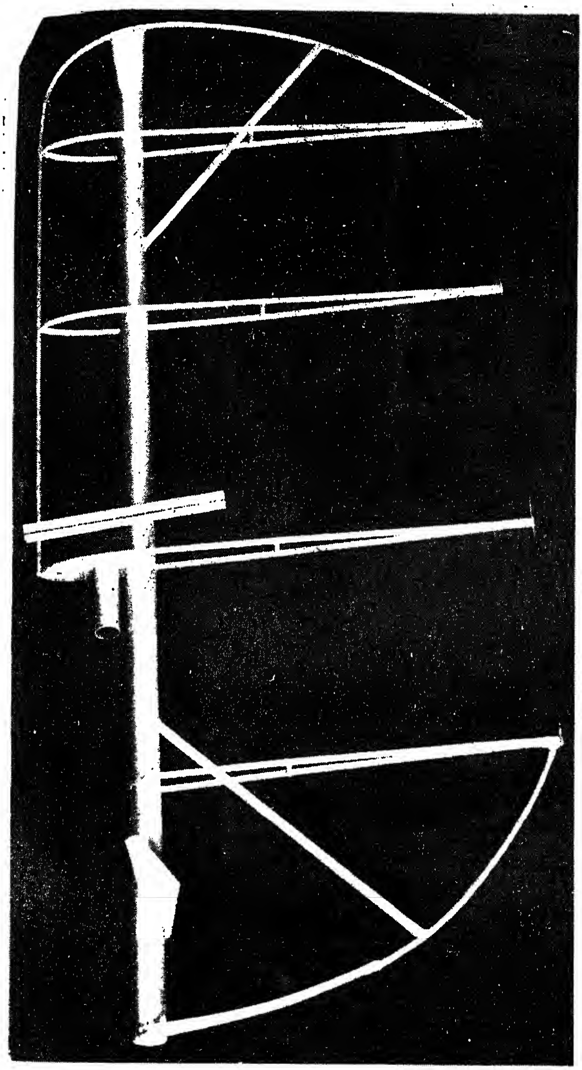
Note: If a metal base jig is used, practically all the welding can be done while the rib is in the jig, thus lessening the danger of the rib warping out of shape.

If it is desired, a short aileron control surface may easily be made up from four of these ribs. They should be spaced 12" apart on a 4'-2" O.D. torque tube. A 4'-1/2" O.D. tube should serve as a spacer to be welded to the central upright. The trailing edge may now be welded into place.

REPAIRS ON STEEL TUBE STRUCTURES

The great majority of airplanes use fuselages built of steel tubing. For the most part, this tubing is chrome-molybdenum steel, S.A.E. 4130, usually referred to as "chrome-moly", but the mild steel, or S.A.E. 1025 tubing is still occasionally encountered. Since it is difficult to distinguish the two materials from one another without suitable testing equipment, it is better to play safe and make any replacements of chrome-moly, unless it is definitely known that the original tubing was 1025.

Other parts of the airplane are also built of tubing, round, square or streamline, such as the landing gear struts, wing struts control surfaces, etc. The same rules that govern fuselage repairs apply also to these other structures, with the exception that the Civil Air Regulations prohibit repairs of any kind to damaged wing brace struts, damaged axles or any members made of streamline tubing. A typical example of a control surface built entirely of round steel tubing is the rudder shown to the right. Damage to the main tube of this part may be repaired by any of the methods shown in the following pages. It would probably not be practical, however, to repair the ribs, as it would be easier to replace them entirely. The twelve inch steel rule is shown so that the relative size of the parts may be estimated. The trailing edge in



BALANCED RUDDER BUILT OF STEEL TUBING

REPAIRS ON STEEL TUBE STRUCTURES
(continued)

this surface is the wire type, which is rather uncommon, but is occasionally used, especially on foreign ships.

As a rule, if an outside sleeve is used in making a splice in tubing, such as those shown in subsequent illustrations, it will be found that a tube with 17 ga. (.058") wall thickness and an outside diameter 1/8" larger than the original tube will make an excellent sleeve, as airplane tubing is usually lighter gage than this except in large sizes. However, the wall thickness of the original should be carefully checked with tubing micrometer, for the replacement tube or sleeve must be at least as strong as the original. The Air Commerce Manual, ACM 18, contains tables listing all sizes of tubes which may be used for replacements in case the original size is not available. It is not considered necessary to include these tables here, as the mechanic should have access to this bulletin when making any major repairs. However, general instructions, as given in Civil Air Regulations, Part 18, are quoted below.

"Welded steel tube fuselages. Damaged members in steel tube fuselages may be repaired by the methods shown in Figures 1 through 8 of ACM 18, if it is possible to have a stub of the length indicated in the figures.

"If the member is damaged at the joint so that it is not possible to have such a stub, the member shall be replaced entirely in the case of web members, and in the case of longerons the splice shall be made in an adjacent bay.

"When it is necessary to remove a member at a joint or cluster, it shall be carefully and completely removed from the cluster without disturbing the surrounding members to which it is attached.

"A replacement tube shall be at least equal in length to the original.

"Where a rosette weld is necessary the hole shall be made in the outside tube only and be of sufficient size to insure fusion with the inner tube.

"Engine mounts. The provisions of the preceding paragraphs shall apply to tubular mount members.

"Landing gears. If damaged landing gear struts are made of streamlined tubing they shall not be repaired unless the method of repair is specifically approved by the Secretary.(See ACM 18).

"If damaged landing gear struts are made of round tubing they may be repaired by using splices similar to those shown in Figures 1 through 8 of ACM 18.

"Damaged axles shall be replaced entirely.

"The straightening of landing gear struts and the filling of kinks with weld material are prohibited.

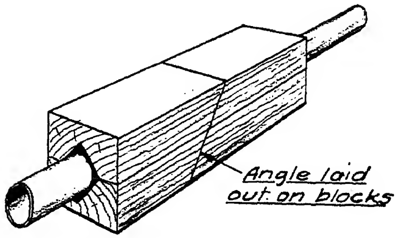
"Wing brace struts. Damaged wing brace struts shall not be repaired but shall be replaced entirely.

"Control surfaces. Repair methods on control surfaces will depend upon the type of construction and the extent of damage. Procedure shall be in accordance with such portions of these regulations as are applicable."

Tubing may be cut accurately to the proper angles in a jig

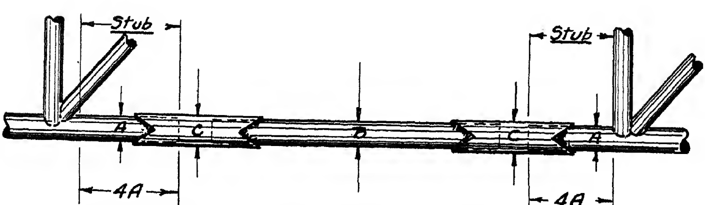
REPAIRS ON STEEL TUBE STRUCTURES
(continued)

made by clamping it between two V-blocks as shown in the sketch to the right. The angle is marked on one side of the blocks, squared across, and marked on the other side. The wood is cut with a fine wood saw, such as backsaw, down to the tubing, then a hack saw is used. An excellent job can be done by using this method. The cut should preferably be made on the side on which the angle is laid out, indicated by the arrow in the sketch to the right. By cutting on the side instead of the top, the cut need not be made entirely through the blocks, which may then be used for other pieces of tubing. However, if a double angle or fishmouth is to be cut, one cut must be made from the top and one from the bottom.



TUBE-CUTTING JIG

Repairs on tubing should not be attempted except by an experienced aircraft welder. Aircraft tubing, especially in fuselages, is likely to be of very light gage - 20 or lighter - and great care is needed to prevent burning or overheating of the weld and adjacent area. Obviously the joint is no stronger than the weld and it is extremely difficult to determine by inspection the quality of the welding. If no competent welder is available and an emergency repair is necessary, it is best to use rivets for attaching the sleeve, as shown on pages 215 and 216, rather than have welding done by an inexperienced person.



A- Original Tube, B-Replacement, C-Outside Sleeve

FIG. I

REPAIRS ON STEEL TUBE STRUCTURES
(continued)

Fig. I shows a splice using an outside sleeve with "fish-mouthed" cut. In laying out this cut, it may simplify matters not to attempt to scribe off the 30° with a protractor, but to measure back from the beginning of the cut a distance equal to 1.75 x half the diameter of the sleeve. This is illustrated in Fig. I-A, and gives an angle as close to 30° as can be measured with a protractor. In assembling the joint, the distance between the station points at each end of the repair should be determined, and the members at these stations clamped to a piece of two-by-four or some equally rigid piece of wood or metal. Tube B should be filled with oil and drained, for though some of this oil will burn off, in the region of the weld, the rest of the tube will be protected, and after the weld cools, a certain amount of the oil remaining will run down over the welded portion. It is well to drill a small hole about 1/8" in diameter near one of the joints to allow the escape of gas that may be formed by the burning oil inside the tubes. The stubs and the replacement tube should be scraped clean of paint or grease on the outside, and one of the sleeves tacked to the stub. The other sleeve is then slipped onto the tube B, and B is inserted into the sleeve which is tack-welded to the stub. The distance that B extends into the stub should be marked on B. The other sleeve is then slipped back onto the other stub for the proper distance. All joints are tack-welded and then the distance between station points is checked again. The joints are now welded and the small hole filled with a Parker-Kalon screw. It is not a bad idea to solder this screw, though if it is a good, tight fit, it is not essential. The welds are cleaned with a wire brush to remove scale, and the tubing primed and painted.

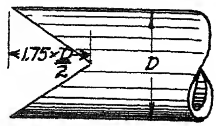
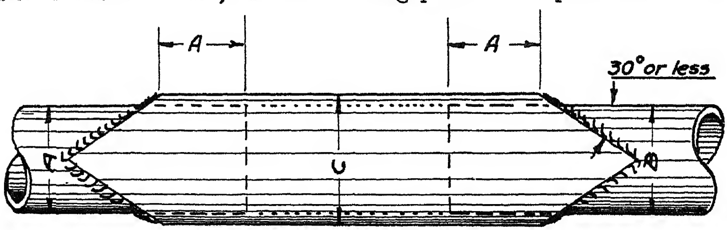
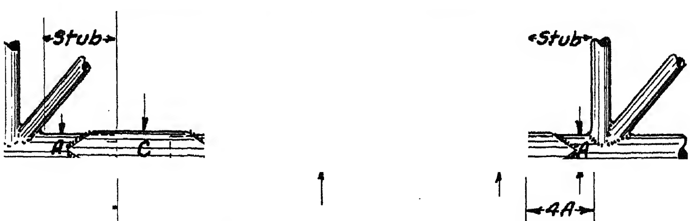


Fig. I-A





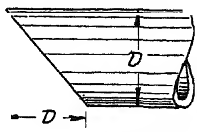
l Tube. B- Replacement Tube, C- Outside Sleeve

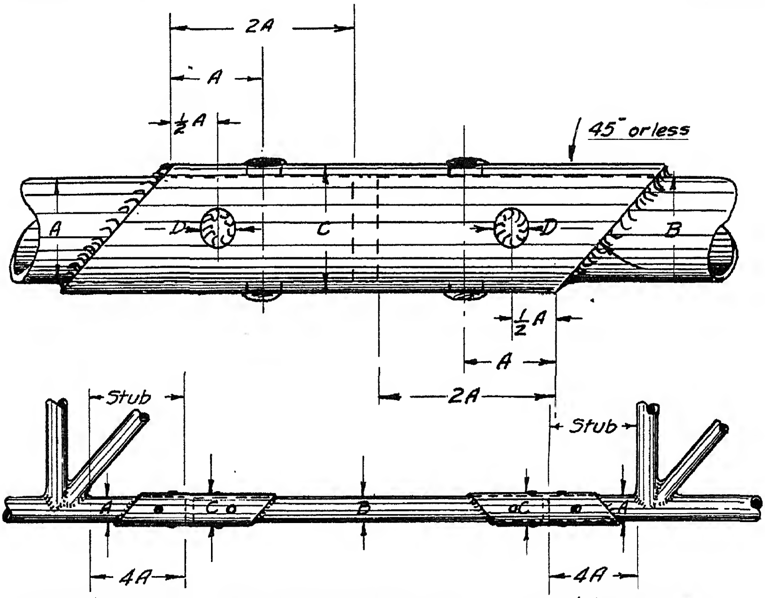
Fig. II

REPAIRS ON STEEL TUBE STRUCTURES
(continued)

Fig. II shows a splice which is almost identical with Fig. I except that the fishmouth is cut the other way. The procedure in preparation and assembly is the same as that given for the preceding type.

Fig. III is similar to the first two except that the sleeves are cut at 45° and not fishmouthed. Fig. III-A shows the method of laying out this cut. It is not considered quite as good as I and II, but is sometimes desirable because of lack of clearance at the end, or for some other reason. The assembly procedure is identical with that employed in the first two.



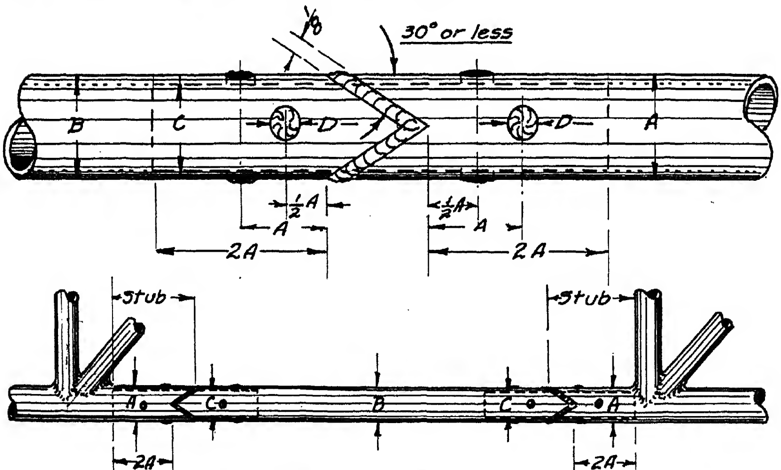


A - Original Tube, B - Replacement Tube, C - Outside Sleeve
D - ¼ A, but not less than ¼", Four rosette welds for each splice
Drill outside sleeve only

Fig. IV illustrates a splice using an inside sleeve. This is somewhat neater in appearance, as there are no bulges as are caused by outside sleeves. However, it is harder to make and harder to weld securely. The inside sleeves must fit loosely enough to slide freely inside of tube B, or else the assembly is impossible if the rest of the structure is undamaged and cannot be pulled apart. If the member which is being repaired is a separate piece, such as a landing gear strut, the sleeves should be tack-welded into the parts of the original tube first, and the replacement piece pushed

REPAIRS ON STEEL TUBE STRUCTURES
(continued)

onto them. However, if it is a structure, like a fuselage, which has been damaged, the sleeves should be carefully laid out and centerpunch marks made at the center of the points where the rosette welds are to be made, so that there will be no doubt later that the sleeve is in the proper location. The holes for the rosette welds should be drilled in the stubs and replacement tube and the burrs left by the drill knocked off on the inside with a round file. This is quite important, as it is essential that the sleeve slide freely inside the replacement tube. The sleeves should then be pushed into the replacement tube just past the end of the latter. Tube B is then put in position, and the sleeves worked into the stubs by driving through the holes for the rosette welds with a very sharp prick punch. When the centerpunch marks mentioned above line up with the center of the holes, the sleeves are, of course, in the proper location and should be welded there. The same rules for finishing apply as on the first type of splice - and in fact should be followed on all splices discussed in this section.



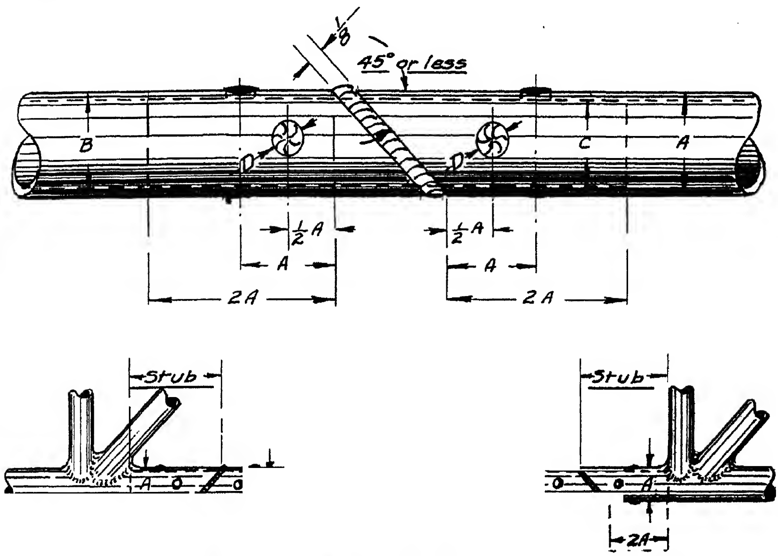
A - Original Tube, B - Replacement Tube, C - Inside Sleeve
D = ¼ A, but not less than ¼. Four rosette welds for each splice
Drill outside tube only

FIG. IV

Fig. V shows approximately the same type of splice, except that the ends are cut at an angle of 45° instead of fishmouthed. The assembly procedure is the same as that for Fig. IV. There is always a temptation where the inside sleeve is used to file down the weld and so make a finished-looking job that shows no sign of repair. This, however, should never be done, as the strength of the weld is likely to be impaired and the Department of Commerce will not pass joints if the weld has been filed. Wire brush, sandblast or abrasive cloth or paper are the only permissible means of

REPAIRS ON STEEL TUBE STRUCTURES (continued)

cleaning up a welded joint. In making the rosette welds through the holes drilled in the outer tubes, care should be taken to actually weld the inner tube to the outer and not merely fill up the hole with welding rod. The same applies to the weld at the joint between the original tube and the replacement, except that here the object is to join the two outer tubes to each other as well as to the inner tube.

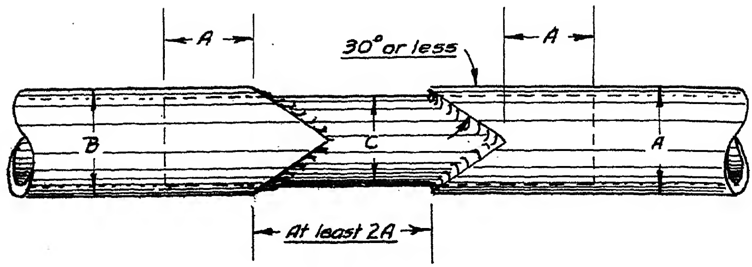


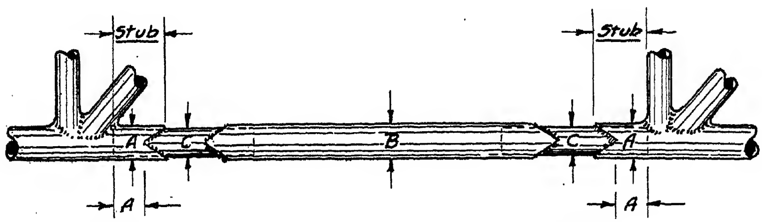
Original Tube, but not less than 1/4"   B - Replacement Tube, Four rosette tube only   C - Inside Sleeve each splice

Figs. VI and VII need little in the way of further exp as the preceding instructions cover them quite fully for the most part. Since there is a space between the original tube and the replacement, there is no problem of working the sleeve out of the replacement tube and into the stub. In some cases, it will be found possible to tack-weld the sleeves into the stubs on both sides of the repair, and in others it will be necessary to tack one sleeve into the stub and slide the other into the replacement. Since the end of the sleeve will stick out, however, the problem presents no difficulties. Just what procedure will be the easiest depends on the relative length of the parts.

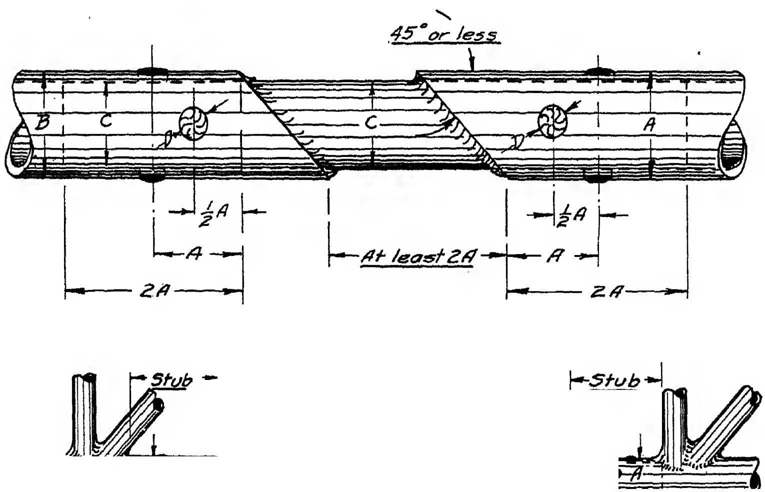
Fig. VIII is the same as Fig. I so far as the drawing goes, but is made to be used with the table at the end of these sheets. It will be noted that this is for very large tubing, much larger than is likely to be encountered in the conventional fuselage.

REPAIRS ON STEEL TUBE STRUCTURES
(continued)



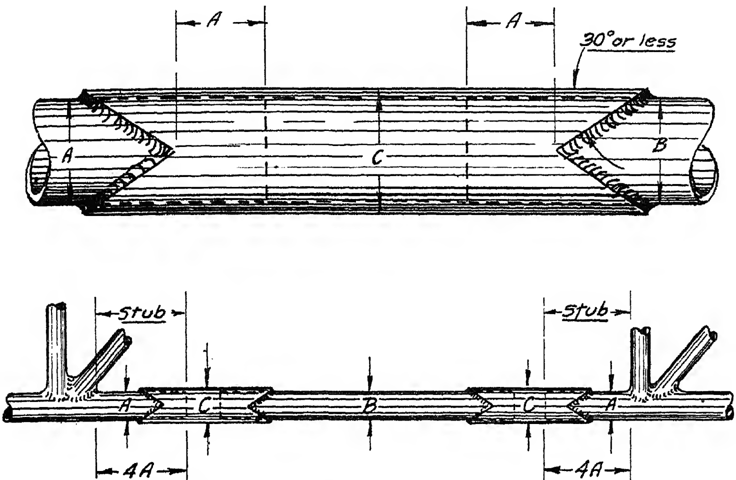


A-Original Tube, B-Replacement Tube, C- Inside



Original Tube, B - Replacement Tube C - Inside Sleeve
¼ Diameter of Tube A, but not less than ¼". Four rosette
h ·. Drill only

REPAIRS ON STEEL TUBE STRUCTURES
(continued)



A - Original Tube. B - Replacement Tube. C - Outside

FIG. VIII

Diameter		Wall Thickness	
A and B	C	A and B	C
1-7/8" Or Less	Diameter A + 1/4"	.095" or Less	.095"
		.120"	.120"
	Diameter A + 3/8"	5/32"	5/32"
	Diameter A + 3/8"	3/16"	3/16" *
	Diameter A + 1/4"	1/4"	1/4" *
2" Or More	Diameter A + 1/4"	.095" or Less	.095"
		.120	.120"
	Diameter A + 1/2"	5/32"	
		3/16"	
		1/4"	1/4" *
* Sleeve C must be reamed to sliding fit.			

Before replacing any portion of a longeron or other fuselage member, the affected stations must be held in the proper positions. If only one side of the fuselage is damaged, these positions may usually be determined by measuring the other side. Otherwise a drawing of the fuselage is necessary, and is desirable in any case. Such drawings may usually be obtained from the original manufacturer.

Having determined the locations of the stations, the points may be laid out on a piece of two-by-four or similar lumber and V-shaped or rounded notches cut to fit the members. This plank is then

REPAIRS ON STEEL TUBE STRUCTURES
(continued

clamped in place, using small V-blocks where the clamps are applied. The station points are given a final check to see that they are correctly located after which the replacement tubes may be fitted and welded in place as previously described.

The following types of repair are recommended by the Army Air Corps, and the illustrations are given in their manual.

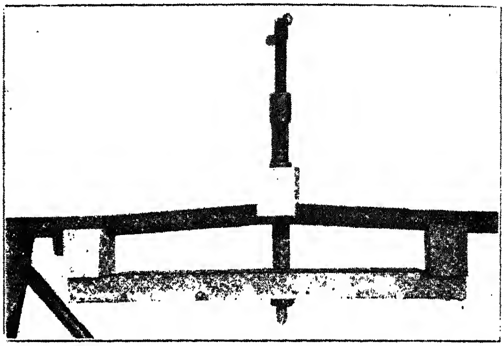


Fig. IX

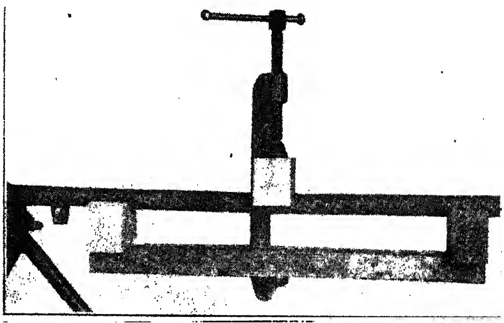


Fig. X

If a longeron or strut is only slightly bent, it may often be straightened by the method illustrated in Figs. IX and X. This method is permissible only when there are no buckles or dents in the tubing. In any case it should be sanctioned by a CAA inspector before the work is begun.

Fig. IX shows a bent longeron. Three blocks of wood are each grooved at one end to fit the longeron. Two of the blocks are attached to a stout piece of wood, the distance between them being such that they fit on the undamaged part of the longeron on each side of the bend. The third block is located on the opposite side at the point of maximum bend and a heavy screw clamp applied as shown. The clamp is tightened until the longeron is bent very slightly in the opposite direction, as shown in Fig. X. It is necessary to carry the tightening until the longeron has passed perfect straightness, as it will spring back. The clamp and blocks are then removed and the longeron checked by laying an accurate straightedge on both the side and the top. It may be necessary to reapply the blocks and clamp several times before the tubing is straight in both directions.

In the case of tubes that are slightly dented, reforming of

REPAIRS ON STEEL TUBE STRUCTURES
(continued)

the damaged area may be accomplished by drilling a block of steel to the diameter of the tube, splitting the block along the axis of the hole and clamping the two halves around the tube with a powerful clamp. A fishmouthed sleeve, long enough to extend well past

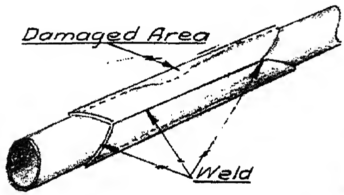


Fig. XI

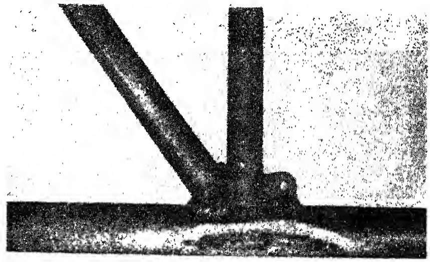


Fig. XII

the re-formed portion, may then be split and the two halves welded around the injured member as shown in Fig. XI. However, the CAA does not look with much favor upon repairs of this nature and permission should be obtained from an inspector before making them.

When a longeron is dented at a station, as shown in Fig. XII, repairs can be made by fitting a patch plate, Fig. XIII, around the damaged member, and welding it in place, forming it to the joint while it is hot, as illustrated in Fig. XIV. There is seldom any difficulty in obtaining approval of this type of repair, provided the job is done in a workmanlike manner.

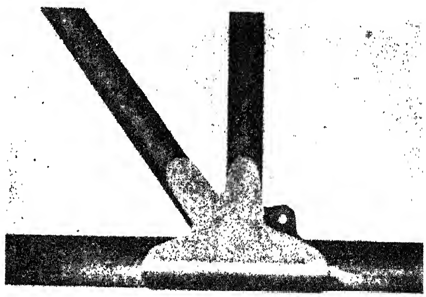


Fig. XIII

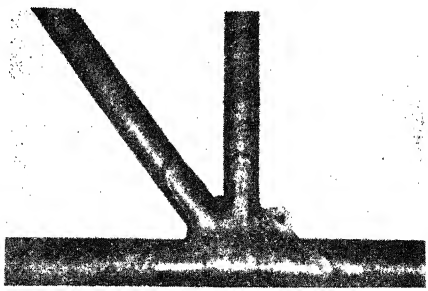


Fig. XIV

PROTECTION OF METALS

While parts made of metal will last almost indefinitely if properly protected, the metals commonly used in aircraft construction will deteriorate through rust or corrosion, particularly if used around salt water, unless steps are taken to prevent such corrosion. This does not apply so much to the corrosion-resistant metals such as stainless steel and pure aluminum, but even they need a certain amount of care and attention.

The matter of protection against rust and corrosion (incidentally, rust is simply one form of corrosion) is important in any structure, but particularly so in aircraft. A bridge, or the frame of a skyscraper, may be built of steel members several inches thick, whereas an airplane usually has many structural members 1/32" or less in thickness. Furthermore, the bridge probably has a margin of safety of 4 or 5, while the margin of safety of some parts of an airplane may be not more than .25. If the members of a bridge rust or corrode to a depth of 1/32", their strength is not materially reduced. Obviously, if the airplane part corrodes an equal amount there will be nothing left. These comparisons indicate why so much consideration has been given to the matter of preventing deterioration in airplane parts and of developing materials which in themselves, and without protective coatings, are highly resistant to corrosion. Some of these, which have been mentioned before, are the various forms of Monel metal and its allied compounds, Alclad, aluminum alloy, and stainless steel. These metals if not brought into contact with other materials, will show little signs of corrosion, even when exposed to the elements for long periods of time.

Generally speaking, corrosion is produced by moisture in the air and the effect seems worse in the vicinity of salt water. This latter fact is rather difficult to understand since the salt in the water probably does not vaporize. Nevertheless, salt air will produce extremely rapid deterioration of any of the metals which are not corrosion-resistant, unless the surface is well protected by some of the means discussed further on in this lesson.

There are two types of corrosion. The first, and least troublesome, is simply a breaking down, or dissolving of the surface by oxidation. The rust formed on the surface of unprotected steel or iron is an example of this type. Since such oxidation is always visible, it may be removed and the surface refinished so that further damage will not occur. The second type, which is much more serious, is known as intercrystalline corrosion. It is caused by chemical or electrical action between the alloys in the metal itself and may not become visible until serious damage has been done. Improper heat treatment of the metal is usually responsible for the trouble, which is found ordinarily in some of the aluminum alloys and corrosion-resistant steels. Surface protection does little in preventing this type of corrosion. If it is discovered, there is no alternative to replacing the parts affected, since the corrosion cannot be checked.

In addition to these distinct forms of corrosion, electrical action may be set up between two dissimilar metals. Anyone who has used the oldfashioned wet battery, or galvanic cell, has no doubt

PROTECTION OF METALS
(continued)

observed that one electrode disintegrates much more rapidly than the other. The reason for this is that every metal has an electric potential and when immersed in a solution (called the "electrolyte") with another metal of a different potential, an electric current is produced. The electrical action between the electrodes eventually breaks down one of them. It so happens that ocean water, or even the salt air, containing water vapor, may act as an electrolyte and permit a reaction between some of the metals used in airplanes, such as, for example, aluminum and bronze, or aluminum and stainless steel. Accordingly, dissimilar metals should not be brought into contact with or even near each other, particularly if the ship is to be used as a seaplane or on an airport adjacent to salt water.

It is, of course, sometimes necessary to bolt or fasten to each other parts made of different metals, such as aluminum alloy and steel. When such an occasion arises, the steel surface should either be plated with cadmium or "metallized" with aluminum, (see further discussion below) and, in addition, given at least two coats of dependable primer before assembly. The faying, or touching, surfaces should be further insulated from each other by fabric soaked with bituminous paint or marine glue. This piece of fabric should extend at least 1/4" beyond the edges of the faying surfaces. Although no plating is necessary when stainless steel is used with aluminum alloy, even greater care should be employed in insulating the two from each other. In the case of copper, brass, or bronze, and aluminum alloy, the copper should be cadmium plated and the insulation provided in the same manner. In no case should copper alloys be used near aluminum or its alloys if the two are likely to be submerged at the same time for any appreciable period.

PLATING

Before parts are plated, they must be thoroughly cleaned, either by <u>sand-blasting</u> or <u>pickling</u>. Sand-blasting consists of blowing, by means of compressed air, some abrasive, such as sand or steel grit, against the part which is being cleaned. It may be used to advantage in removing scale after welding, or for taking old paint out of otherwise inaccessible corners. The sand-blast machine should be used with care, as it will cut through steel or even glass without great difficulty. For this reason, aluminum alloy parts, due to the softness of the material, are seldom cleaned by sand-blasting. The distance that the nozzle of the sand-blast is held from the work and the pressure employed in the blasting depend upon the material being worked. In general, the nozzle should be about 18" from the part being blasted and the pressure about 70 lbs. per sq. in., the nozzle being held directed at the work just long enough to clean the surface thoroughly. After the parts have been sand-blasted they should not be handled with greasy hands or left unprotected. In the case of steel parts, if electro-plating is to follow the sand-blasting, a further cleaning by immersion in a solution of one part hydro-fluoric acid to eight parts of water is desirable. If certain portions of a part are to be sand-blasted and other portions left untouched, the parts which are to be kept free of the sand should be given a coating of heavy grease.

It is usually more convenient to pickle small fittings and

PROTECTION OF METALS
(continued)

other parts instead of cleaning them by means of the sand-blast. If the parts have old paint or grease on them, it may be removed by immersing them in a hot solution of lye and rinsing them in running water. The pickling solution proper is usually composed of water with 5% to 10% (by weight) of sulphuric acid, or 15% to 25% (by weight) of muriatic acid. In case it is desired to mix the sulphuric acid solution, the acid should be poured into the water while the latter is being stirred. Water should not be poured onto the acid, as an explosion may result. While the parts are immersed in the solution, its temperature should be kept about 150° F. When they are thoroughly clean, the parts are rinsed in running water and transferred to the electro-plating bath. If, for any reason, they are not to be electro-plated, they should be immersed in a solution of 20 lbs. of quick lime to 100 gallons of water, following which they are thoroughly rinsed in clean, hot water and dried, usually by tumbling in a barrel of sawdust.

In plating parts with cadmium they are hung by metal hooks from a bar, known as a bus bar, in a solution composed of sodium cyanide, cadmium oxide, caustic soda, and water. A cadmium anode is also hung in the solution. One end of the electrical circuit is attached to the bus bar and the other to the anode and a voltage of from 4 to 12 volts passed through the circuit. This deposits the cadmium directly upon the surface of the parts being plated, the cadmium coating being usually about .0003" in thickness. After plating, the parts are washed in clean water, submerged for one or two minutes in a 3% to 5% solution of chromic acid and washed in clean water again. Paint does not adhere particularly well to cadmium-plated parts, so if such parts are not exposed they are usually given no further treatment. One decided advantage of the cadmium plating is that any cracks which may have previously escaped notice will be shown up as a black line against the silver-gray background produced by the cadmium. This makes the process particularly valuable in the case of any unit which has been welded, heat-treated, or severely formed.

Although cadmium plating is by far the most common and popular means of protecting the surface of metals, particularly steel, there are a number of other processes sometimes used. One of these is galvanizing which consists of plating with zinc either by dipping the parts into molten zinc at a temperature of around 900° F. or by electro-plating. Galvanizing is used widely as a means of protecting parts of buildings and marine hardware. Sherardizing is another method of zinc-plating which is accomplished by heating the parts to be coated in a closed chamber containing zinc-oxide. The temperature used in this process is about 700° F. Parkerizing consists of heating the items to be covered to about 212° F. in a bath of dilute iron phosphate. The surface left after Parkerizing is a good base for paint and the process furthermore will coat the inside of tubular members, which electro-plating will not. Chromium plating is well known to everyone as a finish for automobile parts, small household articles, metal furniture and the like. It is not commonly used in aircraft except for interior trim or for exhibition ships, as it apparently does not stand up as well as some of the other means of protection.

PROTECTION OF METALS
(continued)

Metallizing is not plating in the sense of depositing metal by electricity, but nevertheless consists of coating the surface of a metal which is subject to corrosion with another metal which is highly resistant to corrosion. It has come into wide use because it is an ideal method of applying protective coating to objects or structures, such as fuselages or control surfaces which cannot be conveniently put into a plating bath. Furthermore, no pickling or washing is required. The surface to be coated must, however, be sand-blasted, both to clean and to roughen it. The metallizing process consists of spraying molten metal upon the surface which is to be covered and it may be used on almost any material, even wood, leather, and the like. For although the metal which is being sprayed is melted, it strikes the object in such a finely atomized form that it does not produce any appreciable heat. The equipment is a combination torch and spray gun. A wire made of whatever metal is to be sprayed is fed to the nozzle automatically. It is there melted by an oxy-acetylene flame and sprayed by means of compressed air. Any metal may be used, but naturally it is desirable in aircraft work to use those which resist corrosion, such as cadmium, zinc, or pure aluminum. If the parts being sprayed are likely to be heated afterwards, as in the case of engine cylinders, aluminum is the best metal to use, as when parts which have been metallized with aluminum are heated, the aluminum seems to form a bond with the base metal.

Metallizing is used not only to protect the surface, but also to fill cracks along the seams of floats and hulls. In addition, a worn part may be built up by spraying on layers of the metal from which the part is made until the original size has been restored. The part is then, of course, refinished.

In using the metallizing spray, the gun is held 4" to 6" away from the surface which is being coated and is as nearly perpendicular to that surface as possible, for if the angle between the spray and the surface is less than 45°, the molten metal will not adhere properly. The general procedure is almost identical with that used in spraying paint, which is discussed elsewhere in this book. When several coats are to be put on, the gun is moved during each successive coat at right angles to the direction used in the preceding coat. In this manner the metal may be built up to any desired thickness.

ANODIZING

Aluminum alloy is subject to both inter-crystalline and external corrosion. The former can be prevented by proper heat treatment, but the surfaces must be protected in some manner. Furthermore, paint does not adhere readily to aluminum. To serve the double purpose of making the surface highly resistant to corrosion and also of providing a good base for paint, a process has been developed known as anodizing, or the anodic oxidation process. The result of this process is to produce a surface of aluminum hydroxide on the metal. It is not plating as the anodic coating has no appreciable thickness. A surface which has been anodized is soft and easily scratched and for these reasons should be given a coating of

PROTECTION OF METALS
(continued)

primer before the piece is handled.

The Army, the Navy, and the Coast Guard, all require that parts made from aluminum, or aluminum alloy which contains less than 5% of copper, be anodically treated except in the case of Alclad. Alclad is sufficiently protected by the coating of pure aluminum on the sheet and does not require anodic treatment if it is not to be painted. If paint is to be applied to the part, Alclad should also receive this treatment to provide a good surface for the paint. The anodic treatment is seldom used on castings because the surface is already rough enough to provide a proper base for painting and because in any case they are usually thick enough so that a slight surface corrosion is not highly injurious. Steel and copper parts cannot be anodized and should be left off of any assemblies of aluminum alloy which are to be so treated.

It is customary to anodize the parts before they are assembled, but small assemblies not containing any dissimilar metals, fabric, or seam compounds, may be treated as units. The film deposited by the anodic treatment will penetrate about an inch inside the edge of a riveted joint, but will not coat the metal immediately adjacent the rivet inside the joint. Since, as stated above, the anodic film is very soft, any work which has to be done on the part should be completed before the anodic treatment is given and the metal should be primed immediately after. If it becomes necessary to drill holes for the insertion of rivets after the parts have been anodized, the rivets which are used should be coated with wet primer when they are inserted, so that the raw edges of the drill hole will be protected.

The electrolyte used in the anodic treatment is made of a solution of 5% to 10% of pure chromic acid and water. The anodizing tank is usually made of steel and provided with some means of heating the bath, usually coils of pipe. Another tank must be provided for rinsing. The water in this second tank must be clean and is held at a temperature of 150° F. to 185° F.

If the parts which are to be anodized have any grease or paint on them, they should be cleaned thoroughly. Carbon tetrachloride is sometimes used for this purpose. The pieces are suspended in the bath by means of wires or, in the case of very small units, in containers made of aluminum or aluminum alloy. The anode connection is that from which the parts are hung and the cathode is the steel tank. It is possible to treat large parts in sections by overlapping the films. The temperature of the electrolyte must be held between 91° F. and 99° F. and the voltage is started at about 20 volts and built up to 40, where it is held until the job is finished. The time required depends upon the percentage of chromic acid, a minimum of thirty minutes being necessary with a 10% solution and more time with weaker solutions. After the treatment is finished the parts are washed, using hot water to speed up drying.

Imperfections in the anodic film may be detected by making a mark on the spot in question with an indelible pencil and then wiping the mark with a damp cloth. If the film is satisfactory, the sur-

PROTECTION OF METALS
(continued)

face will retain the pencil mark; otherwise it will be wiped off, and the area must be anodized again. Anodizing shows up cracks just as cadmium plating and is valuable for this reason, aside from its protective effects. Parts properly anodized should withstand for thirty days a salt-spray test made with a 20% sodium chloride solution without evidence of corrosion. If there is such corrosion, the bath should be drained and renewed.

It has been found that potassium dichromate, when applied to anodized surfaces, is absorbed in the coating and greatly increases its corrosion-resistance. The interior of fuel tanks which have been anodized may be protected by boiling them in a 4% potassium dichromate solution for about half an hour. Corrosion of the inside of seaplane floats and hulls may be checked by leaving small perforated cartridges of potassium dichromate at the lowest points along the keel. When salt water collects at such points, small quantities of the chemical will work out into the waterand tend to inhibit corrosion. For this reason it is desirable, when washing out the interior of floats, to use a solution of .5% potassium dichromate (by weight) in clean water. The only disadvantage of using this solution is that it does not readily lend itself to use in a hose, unless a special tank and pump, or compressed air, is used.

MISCELLANEOUS METHODS OF PROTECTION

There are occasions when none of the corrosion-proofing methods previously discussed can be used, so that the mechanic is forced to fall back upon grease and paint. Of the two, it is probable that the proper kind of grease is the better. Painting is discussed in detail elsewhere in this book, so will not be discussed further here. A number of compounds are manufactured especially for greasing metal. These are put out under various trade names such as "Rust-Veto", "No-Ox-Id", and "Corol." One of the most satisfactory compounds of this general type may be very readily made by melting together equal parts of beeswax and commercial white petrolatum. The compound should be boiled for several minutes and stirred thoroughly. When cool, it forms a hard surface and is difficult to rub off. The appearances of any of these greases may be improved by mixing into the boiling compound some finely ground aluminum powder in the proportion of approximately a pound of powder to a gallon of the grease. The mixture should be applied to the parts which it is desired to protect while it is hot, using a small brush or, in the case of large surfaces, a spray gun. If applied with a brush the finish will be rather unattractive in appearance and may be made more sightly by passing the flame of a blow torch lightly over the surface. This causes the surface to melt and become smooth. It should be unnecessary to add that great care should be observed in using the blow torch around the finished ship, particularly in the vicinity of the engine or any portion which is fabric covered.

The inside of all tubes and tubing structures should be protected by drilling 1/8" holes at the ends of the tubes and pumping hot linseed oil or "Lionoil" into the lower hole until it runs out of the upper. The tube is then drained and the holes sealed with Parker-Kalon drive screws. The protection of the inside in this manner is, if anything, more important than protecting

PROTECTION OF METALS
(continued)

the outside, any rust on the outside is more likely to be noted and taken care of. All parts in contact with doped fabric should be covered with dope proof paint or aluminum foil on top of the other finish. Further notes on painting will be found in the section devoted to that subject.

Fittings which are on the inside of wings and other covered surfaces of seaplanes should be dipped in the melted grease before assembly. The same rule applies to bolts, nuts, clevis pins, and the threads of turnbuckles and tie rods, for after bolts or other small parts have been installed, it is impossible to detect rust without removing them; and removal is often inconvenient.

Brass, bronze and copper are not ordinarily protected except by paint. Stainless steel is usually left with its natural bright finish and simply wiped off with light oil every day that the ship is used around salt water.

If it is necessary to corrosion-proof a ship which is already assembled, the inside of all covered surfaces, including the fuselage, should be "fogged" by throwing a spray of very hot Rust-Veto or Corol inside the surface by means of a spray gun. This produces a fine fog or mist of the grease which settles on all the parts and provides fairly good protection. While the fogging is being done, all inspection doors, zippers, etc. should be kept open, so as to provide a maximum circulation of air and assist in blowing the fog into all corners of the structure. The spray gun should be kept in motion, so that there is no heavy deposit built up at one point.

The standard method of testing the corrosion-resistant properties of materials or finishes is the hundred-hour salt spray test. The specimens to be tested are placed in a glass covered cabinet as shown in Fig. I and subjected to a fine spray of salt water for 100 hours. If they show no signs of corrosion or deterioration after this test, it is probable that they will withstand service conditions for a long time without trouble.

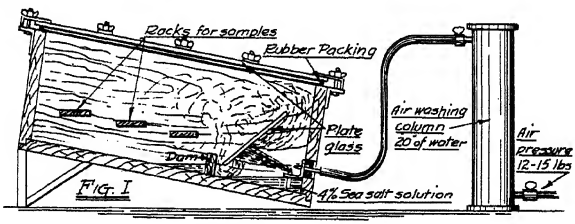


FIG. I

Too much emphasis cannot be laid upon the importance of taking every possible step to prevent the beginning of corrosion, particularly in seaplanes. Careful corrosion-proofing not only eliminates expensive repairs but also adds greatly to the safety of the occupants of the ship, since it tends to eliminate the weakening and possible future failure of important structural members. The proper types and application of primers and paints are discussed later; also special precautions for seaplane maintenance.

FLOATS AND HULLS

It is not the purpose, at present, to discuss the relative merits of the various types of airplanes which use water to "land" on instead of fields, or to take up the general handling and maintenance of such craft. Both of these subjects fall more naturally into the section devoted to "Rigging, Handling and Maintenance", where they will be found. The use of seaplanes and flying boats, however, is becoming more common all the time, and every mechanic should familiarize himself with them.

The word "seaplane" means any airplane equipped to take off from and alight upon the water, but ordinarily it refers to a conventional airplane equipped with floats instead of wheels. Usually the floats and the bracing are interchangeable with the landing gear. A "flying boat" is an airplane in which the passengers, crew and cargo are carried in a hull to which are attached wings and one or more engines. The illustration on the title page of this section shows a typical large flying boat.

Fig. I illustrates three types of seaplanes. The single-float seaplane is seldom used commercially but the Navy finds it more desirable for certain types of work.

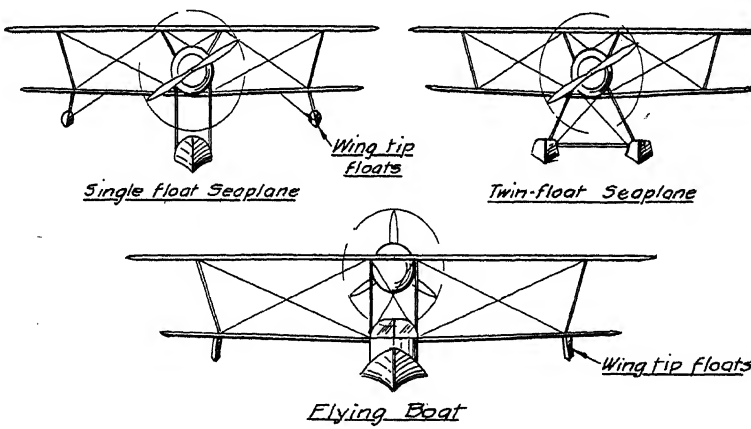


Fig. I

The flying boat shown is a single engine type with the engine mounted as a "pusher", that is, with the propeller aft of the wings. This is considered more satisfactory in small boats, as there is no danger from the propeller while picking up moorings, docking, taking on or letting off passengers, etc.

The "displacement" of a float means the weight of the water it displaces. The "submerged displacement" or "total displacement" is the total weight of the water displaced, if the float were pushed under the surface. The weight of the water displaced is the weight that the float will carry. Thus, if the volume of the float is known, it is quite simple to calculate how

FLOATS AND HULLS
(continued)

much it will carry before it sinks. For example, if the volume of a float is 15 cubic feet, it will sink in fresh water under a load of 15 x 62 = 930 lbs. (The weight of fresh water is approximately 62 lbs. per cu. ft.; of sea water, 64 lbs. per cu. ft.)

Floats are subdivided by bulkheads into a number of water-tight compartments. The number varies with the size of the float but is usually between five and ten. If a leak occurs, unless the damage is extensive, only one compartment will take on water. Floats are always designed with large reserve, or excess, buoyancy, or, in other words, so that they will carry from 80% to 100% more than the total weight of the airplane. Thus, approximately half of the water-tight compartments must be filled before the ship will sink.

The Civil Air Regulations pertaining to floats and hulls are given below:

"Buoyancy (main seaplane floats). Main seaplane floats shall have a buoyancy in excess of that required to support the gross weight of the airplane in fresh water as follows:

(a) 80 per cent in the case of single floats,

(b) 90 per cent in the case of double floats.

"Main seaplane floats for use on aircraft of 2,500 pounds or more maximum authorized weight shall contain at least five water-tight compartments of approximately equal volume. Main seaplane floats for use on aircraft of less than 2,500 pounds maximum authorized weight shall contain at least four such compartments.

"Buoyancy (boat seaplanes). The hulls of boat seaplanes and amphibians shall be divided into water-tight compartments in accordance with the following requirements:

(a) In aircraft of 5,000 pounds maximum authorized weight or more the compartments shall be so arranged that, with any two adjacent compartments flooded, the hull and auxiliary floats (and tires, if used) will retain sufficient buoyancy to support the gross weight of the aircraft in fresh water.

(b) In aircraft of 1,500 to 5,000 pounds maximum authorized weight the compartments shall be so arranged that, with any one compartment flooded, the hull and auxiliary floats (and tires, if used) will retain sufficient buoyancy to support the maximum authorized weight of the aircraft in fresh water.

(c) In aircraft of less than 1,500 pounds maximum authorized weight water-tight subdivision of the hull is not required.

(d) Bulkheads may have water-tight doors for the purpose of communication between compartments.

"Water stability. Auxiliary floats shall be so arranged that when completely submerged in fresh water, they will provide a righting moment which is at least 1.5 times the upsetting moment caused by the aircraft being tilted. A greater degree of stability may be required in the case of large flying boats, depending on the height of the center of gravity above the water level, the area and location of wings and tail surfaces, and other considerations."

The main parts of floats and hulls are shown in Fig. II and the various types of bottoms in Fig. III. Some boat hulls have two steps,

FLOATS AND HULLS
(continued)

some only one, and some have a pointed second step. Most modern floats have only one actual step, the stern acting as a second step. The purpose of a step is to break the suction of the water. If the bottom of the hull were smooth and unbroken, like the bottom of a canoe, for example, the suction of the water, particularly at take-off speed, would be so great that the airplane would never get into the air.

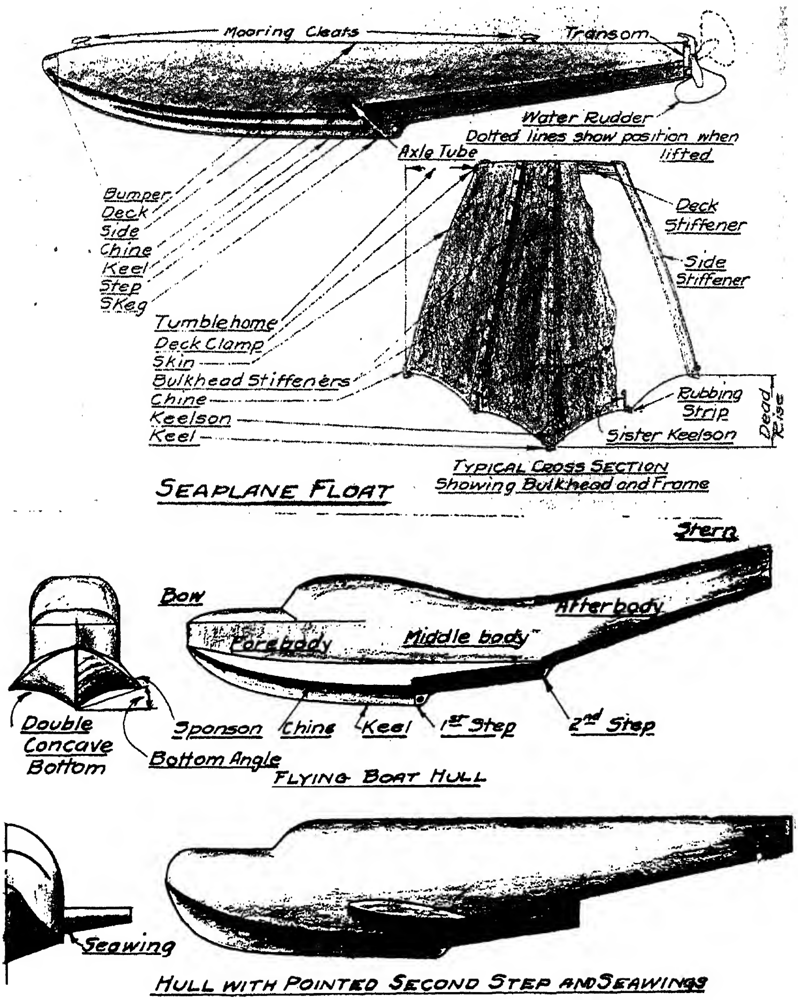
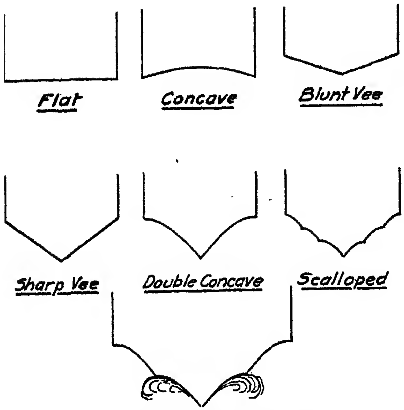


FIG. II

FLOATS AND HULLS
(continued)



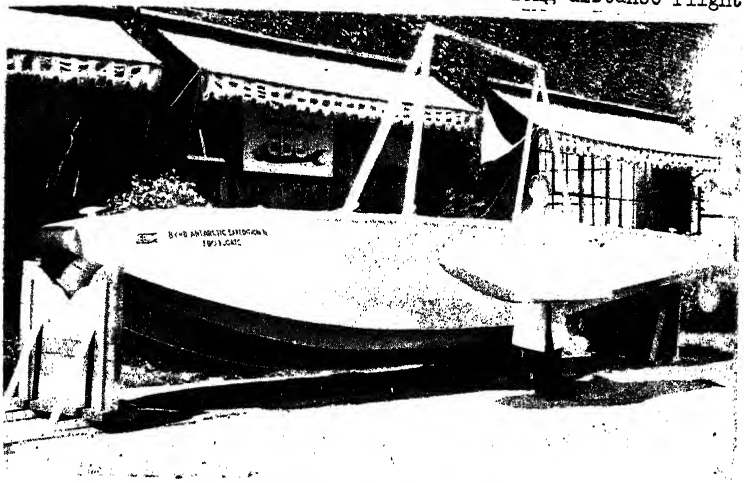
Action of water on scalloped bottom at high speed

Most of the parts of floats and hulls and the descriptive terms which pertain to them are illustrated in Fig. II. However, there is often some confusion between sponsons and sea-wings, and it seems advisable to explain the difference. A sponson is a longitudinal strip or compartment added to the bottom. Its purpose is to increase the width of the bottom, thus adding to the planing surface, lessening spray, and increasing the displacement slightly. A sea-wing is a short wing-like projection, extending from the side of the hull near the chine, and in the region of the main step. It looks very much like a short stub wing, a fact which is no doubt responsible for its name. The purpose of sea-wings is to provide lateral stability in the water. They also increase the planing surface slightly before the ship begins to plane on the step. Ships equipped with sea-wings, as the Boeing "Yankee Clipper" shown on page 67, do not require wingtip floats. On the other hand, tip floats provide greater stability if the ship is heeled over by a cross wind.

The sharpness of the "V" of the bottom determines the ability of the float or hull to withstand rough water. The greater the bottom angle, (see Fig. II) the "softer" the ship will be in rough water. On the other hand, the less the angle the quicker the take-off in smooth water with heavy loads. So, as everything else in airplane design, the bottom must be a compromise. As a general rule, a ship with comparatively high horsepower is equipped with a sharp V bottom, as the reserve horsepower will enable it to take off quickly enough even in smooth water. A low powered ship, since it may have difficulty getting off in a calm, accordingly has a blunt V, or even a flat bottom with no V at all.

The comparative sharpness of the V bottom may be readily noticed in the two floats shown in Fig. IV, which also shows the largest and smallest floats built in this country. The smaller of the two is for a 36 horsepower Aeronca, and the largest is for Admiral Byrd's 1000 horsepower Curtiss Condor. Another illustration of the extremely sharp V is in the floats on Colonel Lindbergh's Lockheed, which carries the same number of passengers as the Aeronca but has over twelve times as much power. The construction of the floats for the

Lockheed is shown in Fig. V. This photograph was taken
tory of the Edo Aircraft Corp., and gives an excellent
water-tight bulkheads, ribs and stringers. These
were equipped with gas tanks to provide for long-distance flights



THE LARGEST AND SMALLEST FLOATS
Fig. IV.

tory view showing other floats in the pro-
cons ...ion. It will be noticed that they are built upside
This the usual procedure in building floats and hulls as

Fig.VI.

FLOATS AND HULLS
(continued)

Courtesy EDO Aircraft Corp.

Construction of Floats for Lockheed "Sirius"

FIG. V

FLOATS AND HULLS
(continued)

the bottom is put on first and the riveting is more easily done with the bottom up.

After the floats are finished, they are water-tested, both for leaks on the bottom or sides and between water-tight compartments. To the rear of the float shown in Fig. VI may be seen the device for filling and emptying the compartments. Any loose rivets are tightened and the float is then given what is known as the "anodic" treatment to prevent corrosion. It is then primed with zinc chromate primer and painted.

Most of the riveting is done with pneumatic riveting guns, though squeeze riveters are used wherever it is feasible, as it requires only one man to use a squeezing device, whereas, two are required with any other method, one to rivet and one to buck.

It will be noted that the foregoing discussion pertains only to metal floats and hulls. Early construction was of wood, the frames being ash or white oak and the skin of built-up plywood. Wooden floats of this type, however, absorb a great deal of moisture - as much as half their weight in some cases - and for this reason metal construction became universal many years ago. With the development of phenolic plywood and structures of the Duramold type previously discussed, wood may again occupy a prominent place in seaplane design.

Pneumatic floats have also met with some success. These are built by McKinley Pneumatic Floats, Inc., and are made of airship fabric. This fabric is three-ply long fibre cotton, rubberized to make it air and water tight. Hence, the floats are sometimes referred to as "rubber" floats. The shape of the floats is maintained by the way in which the material is cut and by inflating them with air to a pressure of one to three pounds per square inch. The only additional stiffening is provided by a backbone or wide strip of aluminum alloy which extends the length of the deck and furnishes a means for attaching the struts and bracing as well as a walk by which passengers can enter or leave the cockpit. Four or five diaphragms subdivide the float into a number of water-tight compartments. Repairs are made by cementing a patch over the damaged area, as in the case of an automobile tire. The inventors claim many advantages, among which are low weight, low cost, freedom from shock in rough water or in striking obstacles, and simplicity in maintenance and repair.

REPAIRS ON FLOATS AND HULLS

Seaplane floats and flying boat hulls are subject to damage from striking floating debris, from landing and taking off in water that is too rough, from running onto rocks or from unnecessary abuse in beaching or docking. There is no essential difference in repairing hulls and floats. Hulls may seem somewhat more accessible, but when the seats, floors, upholstery etc., have to be removed it will probably be found that more work is involved than in making a similar repair on seaplane floats.

As previously mentioned, at present the majority of floats and hulls are made of metal, usually aluminum alloy. For this reason, the discussions on repair and maintenance which follow pertain only to construction of this type. Wooden floats may be repaired just as any other wood or plywood structures, which are discussed in the first section of this book.

The following instructions on repairs are taken from the Service Manual of the Edo Aircraft Corporation, the largest manufacturers of seaplane floats in this country.

"There are no mysterious or extraordinary difficulties about repairing aluminum alloy structures. By reading these instructions and examining the rivets in the floats, a mechanic and helper should learn to take out and put in rivets in a few hours' time and practice can be obtained on scrap pieces of metal before starting on the actual float.

EQUIPMENT. The tools required are a drill, tin shears, hack saw, file, hammer, wooden mallet, small cold chisel, rivet set and a bucking bar. A rivet set is a punch with a concave end of the size which one wishes for the head of the rivet. The bucking bar is an iron or steel bar weighing from one to five pounds which is pushed up against the head of the rivet, and as a rule the heavier the bucking bar, the better the job. The part of the bar pressing against the rivet can be either smooth or slightly roughened so as to get a better grip on the rivet.

The material required is a piece of alclad sheet, some rivets, Parker Kalon screws and machine screws, (cadmium plated, if possible), as well as some friction tape or flannel cloth, Bitumastic solution, and seam filler. The proper rivet to use is the aluminum alloy A17S-T, as supplied by the Aluminum Company of America or the Edo Company. Ordinary duralumin rivets can be headed cold without heat treatment, but they are harder to head and if overworked will become brittle and crack. It is very important not to use any brass or copper rivets or screws, as these will cause very rapid corrosion of the alclad.

TAKING OUT RIVETS. Rivets can be removed by knocking their heads off by a sideways blow with a small cold chisel. A single smart blow with a hammer will knock the head off, whereas, a series of gentle blows tear the sheet. As a wide cold chisel cuts into the sheet, it is best to grind down a center punch or rivet set so that the end is at a slight angle and has a flat elliptical

REPAIRS ON FLOATS AND HULLS
(continued)

face of about three eighths of an inch. This tool, if used as a cold chisel, is less likely to cut into the sheet. It is also a good plan for a helper to buck the rivet from the inside, especially if the rivet is in thin sheeting. The head having been knocked off, the shank of the rivet can be knocked out with a punch. If the float has been painted several times, it is best to first remove the paint around the rivet head so that work can be seen better.

An excellent precaution to take before attempting to knock off the head of a rivet is to drill some distance into the head with a drill somewhat smaller than the shank. This weakens the head and it can then more easily be removed. To properly start the drill a center punch mark should be put in the center of the rivet head. Great care should be taken not to drill completely through the head for fear of injuring the sheet, since even by starting the drill from a center punch mark, it is very difficult to drill down the shank without penetrating through the side. With a little practice, however, especially if an electric drill is available, it is very easy to weaken the head and then knock it off with a cold chisel without in any way damaging the metal or enlarging the rivet hole.

DRIVING RIVETS. If the rivets have been removed carefully, the same sized rivet as used originally can be replaced in the holes. The shank of the rivet should project out a distance equal to about 1-1/2 or 2 times its diameter. In the factory the large assortment of rivets makes it possible to always have the proper length on hand. In the field, however, it will usually be necessary to use long rivets and cut off the shank to the required length with a pair of cutting pliers or small tin shears. The rivet is normally put in and bucked from the inside so that the head is formed on the outside, and it is well to daub the hole with Bitumastic solution, to prevent leakage and corrosion. Until experience has been gained the rivet should not be set too tight. A loose rivet can be tightened but too much hammering may injure the sheets causing dents and tending to expand the metal so that it bulges out between rivets.

There are two essentials in properly driving rivets. In the first place, the bucking bar must be really pressed and held tightly against the rivet. It is sometimes difficult to see whether the bucking bar is up tight, and in such case the man on the outside should check it by trying to push the rivet in before he starts putting a head on it. In the second place, the sheets of metal which are being riveted, must be drawn tightly together before riveting is started. This can be accomplished by the free use of machine screws in preliminarily clamping the sheets together.

If many rivets are to be put in a special draw set can be used to advantage. This is essentially a rod with a hole drilled in one end to a size 1/32" larger than the shank of the rivet and short enough to expand the head of the rivet at the same time that it draws the metal together. After the rivet has been placed in the

REPAIRS ON FLOATS AND HULLS
(continued)

hole and bucked, a few blows are given with this tool before driving it. If the rivet is properly driven and the sheets drawn together, a water tight joint is assured. If the sheets are not drawn together, the shank of the rivet will expand between the sheets and although the rivets may look all right from the outside, water will leak in between the sheets.

It is advisable to use a rivet set to put the head on the shank of the rivet and it is important to hold it parallel with the shank or else a defective head will be formed. Eight or nine blows with a medium weight hammer on the set should be sufficient to form a good head. There are a few awkward places in the float where it is very difficult to insert a rivet from the outside. In these cases, insert a wire through the hole in the float from the outside. This wire can be fastened to the rivet by filing a point on the rivet and drilling a hole through the narrow part. The point of the rivet is then drawn through the hole by pulling on the wire. Do not unfasten the wire until sure that the rivet is properly bucked from the inside.

Where compressed air from 80 to 150 lbs. pressure is available a Tupe "U" Boyer compressed air scaling hammer, costing about $45.00 and obtainable from the Chicago Pneumatic Tool Company, will drive rivets in about half the time required by hand. In this case, the rivet is pushed into the hole from the outside and the hammering is done against the head of the rivet. The pushing up of the bucking bar against the shank of the rivet forms a head on the inside. This type of hammer requires care in handling and is not recommended unless extensive rebuilding work is to be accomplished.

STRAIGHTENING DENTS. If a float has been slightly dented it can be hammered back into shape by placing a flat piece of wood against the deformed part and hammering on the projecting material with a wooden mallet. A stick of wood pounded with a hammer will often reach spots where a mallet can not be used. Where dents have produced very sharp bends in the metal, they can still be hammered out but in this case it is advisable to reenforce them by putting on a patch (as described in the next paragraph "Patching"), even though the flattening out of the metal has not caused any apparent cracks.

As previously noted, the portion of the bottom, just forward of the step plays a most important part in the take-off characteristics of the floats and if it is even slightly dented or deformed it may make itself felt by a tendency to porpoise or nose over in high speed conditions on the water. For this reason, even small dents must be corrected in this area, but with this exception they had probably best be left alone, since hammering changes the molecular structure of the metal, weakening it and making it more subject to corrosion, and in the absence of heat treating facilities as little should be done as possible.

PATCHING. Welding any part of the floats must be absolutely prohibited since it is extremely difficult to accomplish, and at

REPAIRS ON FLOATS AND HULLS
(continued)

the same time would destroy the strength of the heat treated metal as well as the alclad protective film. For this reason, where the metal has been cracked, punctured, or requires reinforcing, a patch is always applied, and the operation should be performed with care.

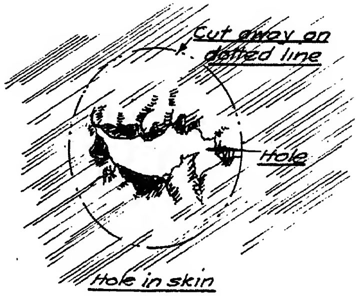


FIG. I

Never try to patch over a dented or torn piece of metal, until it has been hammered back into shape, as described above. Before making a patch, the paint should be removed and the region of the damage carefully examined for cracks or tears radiating from the edges and these should all be cut away. Having determined the extent of the damage, the edges should be trimmed out with shears or a hack saw, so as to form a symmetrically shaped hole with sound metal all the way round, and carefully smoothed down with a file. See Fig. I.

The next step is to cut out a patch large enough to overlap the edges of the hole by approximately 5/8" all the way round, using alclad sheet, one or two gauges heavier than the damaged material. A row of rivet holes should then be laid out and center punched on the patch, 1/4" in from the edges of the patch with a spacing 3/8" on centers. Unless the material is over .040" thick rivets of 1/8" diameter should be used; for heavier gauges 5/32" rivets should be used.

To apply the patch, three or more holes should first be drilled through both the patch and the piece under repair and machine screws put in so as to hold the patch in place, until the balance of the drilling and rivetting is completed. See Fig. II. Be sure and have the patch set firmly against the float before drilling or else they are likely to be found out of alignment when rivetting is started. The patch should always be applied from the outside, and drilling will be greatly facilitated if a block of wood is held against the metal from the inside. To insure water tightness, it is well to place a layer of flannel

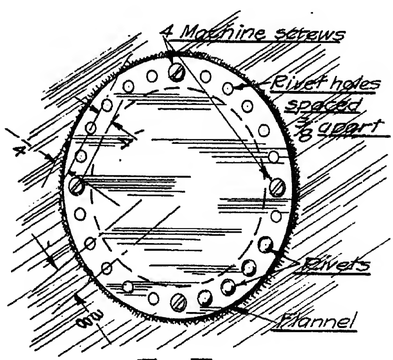


FIG. II

REPAIRS ON FLOATS AND HULLS
(continued)

soaked in Bitumastic solution between the patch and the metal under repair.

PATCHING WITH SCREWS. Where rivets are not available or where because of lack of time or facilities, it is impractical to use them, Parker Kalon thread cutting metal screws or steel machine screws may be used for temporary repairs. Both are put in with heads on the outside, and can generally be purchased from any hardware jobber. Since Parker Kalon screws are set with a screw driver they have the advantage of not requiring any attention from the inside of the float which is of great value in emergency use and where difficult spots must be reached. It is very important, however, to use exactly the right size drill before setting them in place since otherwise their effectiveness will be much impaired. This size will generally be found on the box. They should be long enough to protrude through the sheets with one thread showing. Both machine and Parker Kalon screws are, of course, only temporary and should be replaced with rivets at the first opportunity.

REMOVING DECKS. Removing the decks gives good space to work in and usually means quicker and better results in case of general overhaul or major repairs. It is accomplished by knocking out the rivets and where the damaged area is localized, it often saves time to remove only the section of deck between two bulkheads. This is done by cutting the deck sheet with a drill and hack saw. To make the cut strong and water tight when replacing it, an extra strip about 1-1/2" wide is lapped over the joint. In the shop two men can generally remove the decks of an average size pair of floats in a morning and put them back in a day.

The same holes are used in putting decks back. The rivets fastening the deck to the stringers and bulkheads are put in and bucked from the inside by reaching through the handhole covers, and rivetted in the usual manner. In case of floats having an outside upstanding seam, however, the rivets can be squeezed with a considerable saving in time. A large wire cutter about three feet long with specially cupped jaws can be used for the purpose. Such a tool can be supplied by Edo or made up at any machine shop.

Special precautions must be taken in removing and replacing decks on those float models in which the spreader tubes are attached to the upstanding seams (see illustrations under "Rigging, Handling and Maintenance") in order to be sure that the strength of the fitting is not impaired. The danger lies in improperly replacing the steel "U" clip, and every effort should be made to use the original holes for the rivets, since drilling new holes would seriously weaken the vertical stiffener. If new deck and side sheets and vertical stiffeners are used, it is extremely important to see that the "U" clip is driven firmly home before drilling, since otherwise the holes might only pierce the edge of the metal resulting in a complete loss of strength in tension.

REPLACING SHEETS. Where a large area is damaged it makes a better job to remove a section of the sheets instead of trying to

REPAIRS ON FLOATS AND HULLS
(continued)

put in a very large patch. Such a replacement should extend at least the length between two bulkheads, and the joints should be made at the bulkheads, rather than between them. In splicing on a new sheet a double row of rivets should be used on the bottom although a single row will suffice in the side. In most cases it is easier to put both rows on the flanged side of the bulkhead. Although it takes more time, it makes a better job if a reinforcing strip is put on the inside of the bulkhead flange. It is very important that the old holes in the original metal match exactly with the holes drilled in the replacement sheet or patch. Otherwise, if new holes are drilled between the old holes it will so weaken the sheet as to seriously affect its strength.

To insure matching of the holes either drill the patch from the inside using the old holes as a guide, or else mark the patch very carefully with a pencil so that the center of the mark is exactly over the center of the hole. In thin sheets, in cases where a drill will not reach a hole from the inside, it is possible to push a sharp instrument such as an ice pick or center punch hard up against the inside of the sheet. By hammering lightly on the outside of the sheet with a mallet a slight projection results which can serve to locate the hole.

REPAIRS OF BUCKLING - INTERNAL FAILURES. If the side sheets have been slightly wrinkled by very hard landings they can be bumped out by bracing the outside of float at the bulkheads and hammering from the inside with a board hit by a wooden mallet. The stringers can generally be straightened in the same manner and it is then advisable to rivet some extra ones on the inside to keep the damage from spreading. If the float is buckled to a point where there is a sag of more than one quarter of an inch in the deck line or the bottom stringers in the flat portion forward of the step, or if the side sheet wrinkles are very sharp, it will probably be necessary to remove the deck to make a thorough inspection and replace those stringers which are bent.

There is also a possibility that the sheets will have been strained so that they may crack when straightened. If this is the case it is generally advisable to remove the damaged ones and splice on a new section.

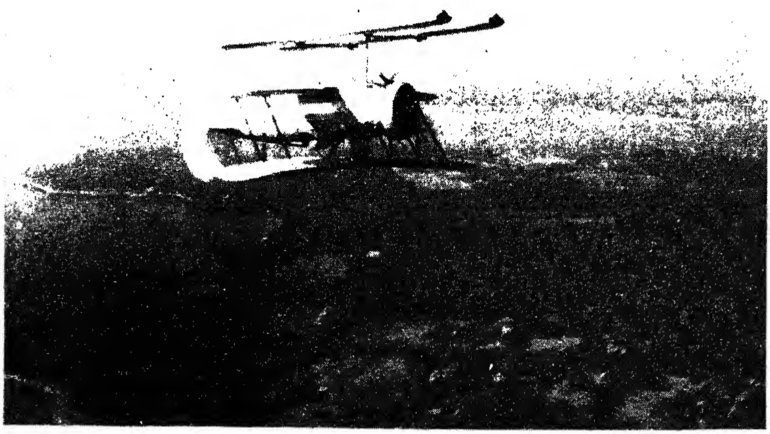
In the case of a float which has been seriously buckled the bulkheads should also be carefully examined for buckling or cracks particularly at the bottom, near the flange. If the buckle is not bad it can be hammered out and a reinforcing plate fastened on. This should usually be flanged over and fastened on the opposite side from the existing flange. If the buckling is so bad that the bulkhead has cracked, it is advisable to saw out the bottom half and rivet on a new portion. Bulkheads of production floats are generally stamped at the factory to standard sizes and it is usually easier and cheaper to obtain a new one than to try and form one. Except in cases of minor buckling, it will generally be necessary to remove the bottom as well as the deck in order to properly replace a section of bulkhead.

REPAIRS ON FLOATS AND HULLS
(continued)

REPAIRS AFTER SERIOUS CRASHES. So long as either the deck or the keel of the floats remain straight and the whole structure has not been hogged and buckled, repairs in the field can generally be made, as described in the previous paragraph. A pontoon which has actually been buckled in a crash, however, is very difficult to repair without replacing it on an assembly jig, since a whole section will probably have to be removed. If the damage appears to be of such a very serious nature, it is advisable to have photographs taken from several angles and sent to the Edo factory with as complete a description of the damage as possible, so that detailed advice can be given.

Sometimes, as a result of a serious crash, or where the propeller has cut through the float due to a strut failure, it is found that the bow of the float is hopelessly damaged, whereas, the rest of it is in excellent condition. In cases of this sort it is frequently practical to cut away the entire damaged portion and splice on a new section supplied from the factory.

REPAIRING STRUTS. In the case of crack-ups, where struts and spreader tubes have been damaged, the struts themselves can be repaired by welding on reinforced sleeves or patches of ordinary aircraft sheet steel or tubing. It is important, however, to be sure that repaired struts are oiled inside, drained, and hermetically sealed so as to prevent internal corrosion. The spreader tubes are made up from chrome-molybdenum steel tubing and have been subjected to heat treatment. If they are damaged in any way, therefore, it is not permissible to repair them under ordinary circumstances and factory replacements will be required.



Courtesy EDO Aircraft Corp

Floats are not likely to be damaged in this position

METAL WINGS

There are three types of wings employing metal for parts other than fittings. There is the composite type, with wood spars and metal ribs, such as that shown in Fig. I. This type is covered with fabric and differs little from the all-wood, fabric-covered construction. The metal ribs are used because the designer believes them to be more economical in respect to cost or weight, or both.

Fig. I
IRELAND FLYING BOAT WING WITH STAMPED DURAL RIBS

The next type is that with metal spars and metal ribs, covered with fabric. The Stinson wing shown in Fig. II is an example. About 25% of the modern airplanes use this type of construction.

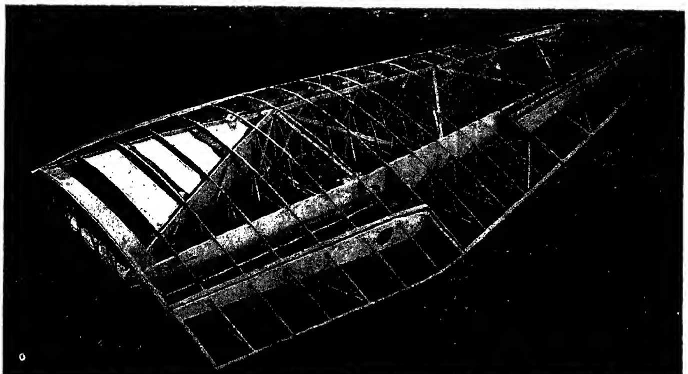


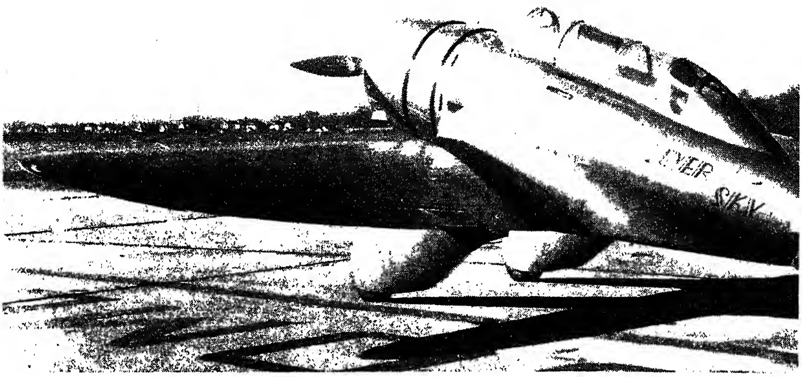
Fig. II
STINSON WING - NOTE FLAP NEAR ROOT

The third type which includes about 35% of all those built is made entirely of metal, including the cover. Practically all of the large transport ships and many of the military planes. both large and small use this form of construction.

Metal-covered wings usually are designed so that the cover or skin carries the drag loads and no drag wires are used. When the skin carries load, the construction is known as the "stressed-skin" type. In some cases, the skin also reinforces or relieves the beams of some of the stresses caused by the lift. In other designs, especially the multispar form of construction, where there are three, four, or five beams, instead of the more usual two, no ribs

METAL WINGS
(continued)

are used, as the skin is stiff enough without them. Fig. IV is an example of the multispar construction - with ribs, however, of



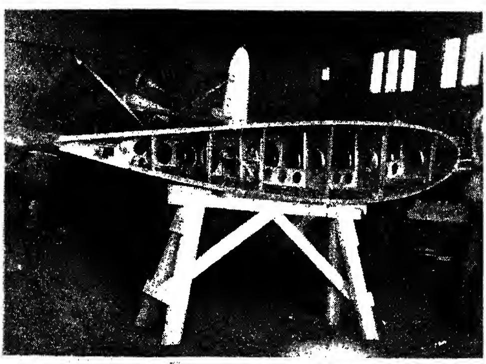
Courtesy Seversky Aircraft Corp.

Fig. III
ALL-METAL WING ON SEVERSKY BT-8

stamped dural. However, when the ribs are left out, the skin is usually corrugated, with the corrugations running from leading to trailing edge. The Ford Trimotor is an example.

Sometimes a combination cloth and metal cover is employed. The Sikorsky wings shown in Figs. V, VI, and VII, illustrate this type. The whole front section, as seen in Fig. V is, in effect, a single wide beam.

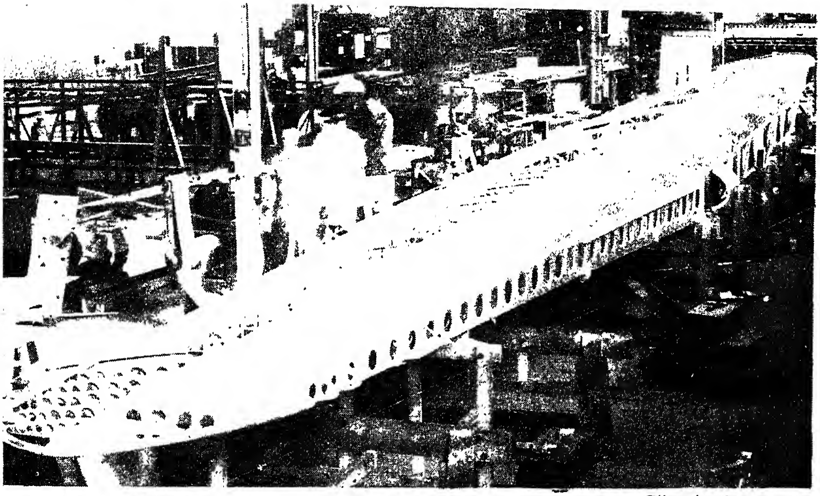
Extensive repairs on metal wings are usually difficult and in many cases must be done at the factory or at least by an approved repair station. Due to the wide variation in designs, it is impossible to give any specific instructions in regard to repairs, for each job presents its own problems which must be solved as encountered. The advice of a Civil Aeronautics Authority Inspector is likely to prove of great help. The following paragraphs are taken from C.A.R. 18.



Courtesy Aero Trades Inc.

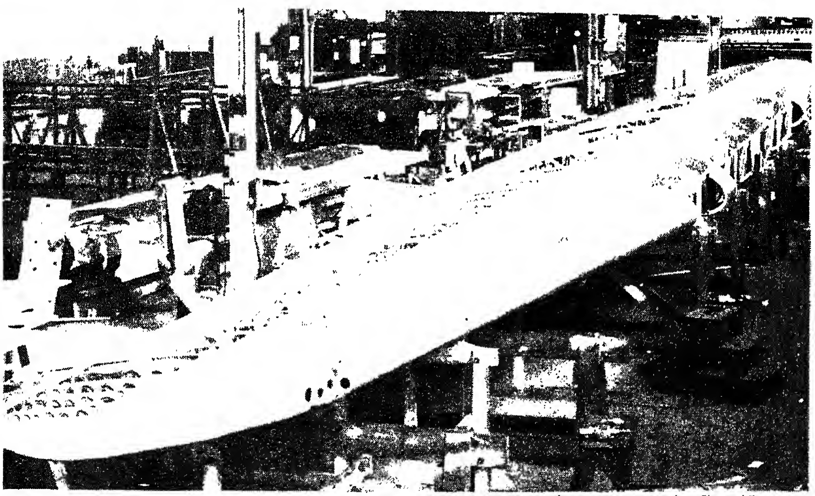
Fig. IV
NORTHROP WING- NOTE FLAP OPENED

METAL WINGS
(continued)



Courtesy Sikorsky Aircraft

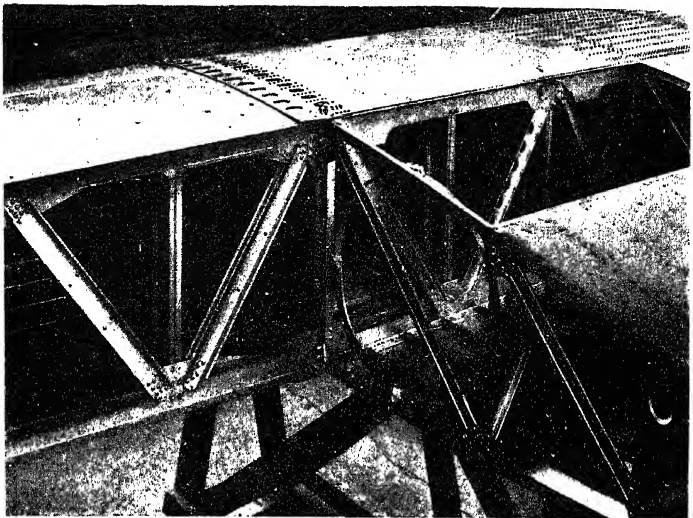
Fig. V
SIKORSKY WING UNDER CONSTRUCTION. NOTE FRONT BEAM WITH FLANGED LIGHTENING HOLES



Courtesy Sikorsky Aircraft

Fig. VI
THE SAME WING AS IN FIG. V, WITH NOSE ATTACHED

METAL WINGS
(continued)



Courtesy Sikorsky Aircraft

Fig. VII
DETAILS OF SIKORSKY WING CONSTRUCTION WITH PLATES REMOVED TO SHOW GAS TANK CRADLE

"Wood or metal covered (stressed-skin) wings.

Repairs to damaged stressed-skin or monocoque types of wing structure shall be made at the factory of origin or by a certified repair station recommended in writing by the manufacturer for this type of work. Such station shall make such repairs in accordance with specific recommendations from the manufacturer.

"Small holes which in the discretion of a C.A.A. inspector do not seriously impair the strength of the structure may be repaired by, or the repair may be supervised by, any certificated airplane mechanic, provided the specific recommendations of the manufacturer governing such types of repair are followed. Small holes may be patched by attaching a cover over the hole.

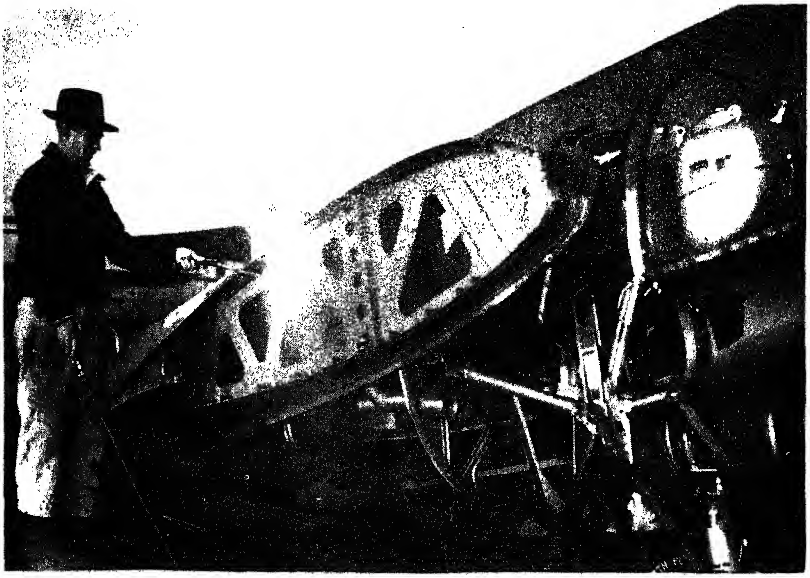
"In any case, repairs to damaged skin, if very extensive, shall be made by replacing an entire panel from one structural member to the next. Where holes are large, the seam shall be made to lie along a bulkhead or along a structural member.

"Wood or metal monocoque fuselages.

"The provisions of the preceding paragraphs apply to this type of structure."

METAL MONOCOQUE FUSELAGES

The word monocoque is derived from two words meaning "single" and "shell" respectively. This is quite descriptive of the monocoque fuselage, which instead of depending upon a truss or steel



CLEANING WING STUBS OF A LOCKHEED BOMBER

tubing or other material, carries the loads from the tail surfaces, etc., in a shell of metal or wood. This is the true monocoque type. The semi-monocoque presents the same outside appearance but instead of relying entirely on the skin for strength incorporates longerons or stringers, usually riveted to the skin, and carrying the main portion of the load. Or it might be said that the longerons and the skin mutually reinforce each other. Either of the two types is referred to as "stressed-skin" construction.

The great majority of the all-metal airplanes employ the semi-monocoque form. It is particularly desirable, as compared with the steel tube cloth covered construction, in the case of large transport ships as more clear space is left for the cabin, doors may be located more conveniently, and the interior fuselage in general is less likely to be cluttered up with bracing. It is also excellent for very fast ships as a more perfect streamlining is usually possible.

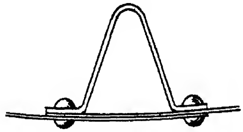


FIG. I

FIG. II

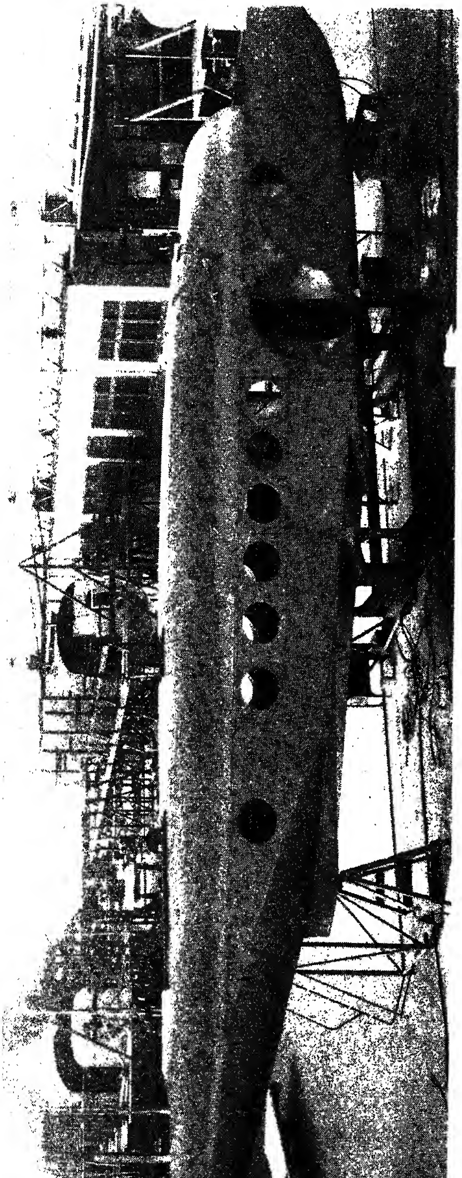
METAL MONOCOQUE FUSELAGES
(continued)


INTERIOR OF LOCKHEAD 'ELECTRA' FUSELAGE

Courtesy Aluminum Co. of America

The longitudinal members in a semi-monocoque fuselage are held apart by bulkheads or formers which give the fuselage its shape. These are usually made of the same material as the skin which is almost invariably aluminum alloy. The skin is put on in long strips riveted to each other and to the stringers and formers. A favorite type of joint is that shown in Fig. I. This has the advantage of providing a double row of rivets through each of the adjoining strips of skin and the stringer at the same time. It also makes a "closed" member out of the stringer, which results in much greater strength than would be developed by an open member such as shown in Fig. II, though the latter type is sometimes used for very light stiffeners which do not transmit high loads.

METAL MONOCOQUE FUSELAGES
(continued)



Courtesy Sikorsky Aircraft

ALL-METAL MONOCOQUE FLYING BOAT HULL UNDER CONSTRUCTION
NOTE CONSTRUCTION JIGS IN BACK GROUND

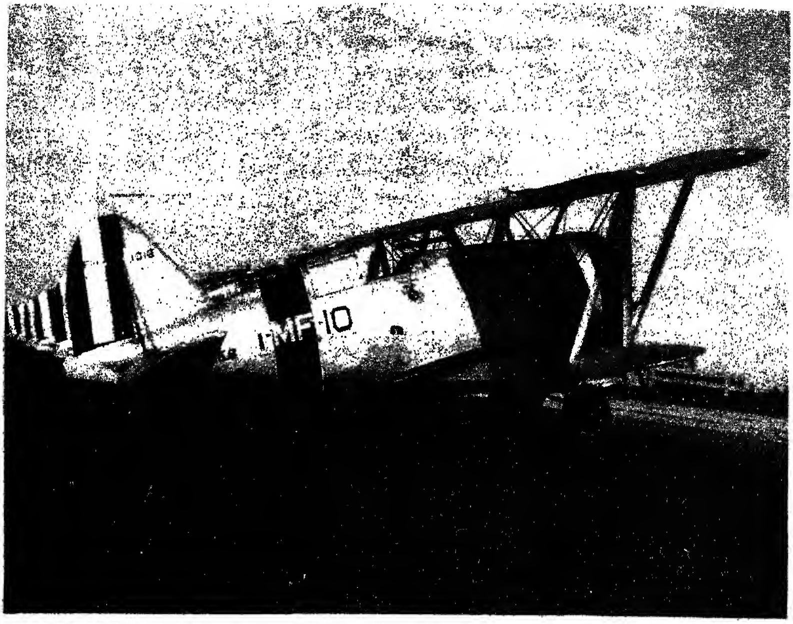
Repairs on metal monocoque fuselages follow the same general procedure outlined for repairing floats and hulls. Small holes may be patched in the same manner as holes or cracks in cowling, discussed on preceding pages. Major repairs, such as replacing damaged bulkheads, are very difficult and should not be attempted by the field mechanic.

The Department of Commerce regulations governing repairs on all-metal stressed-skin wings also apply to fuselages.

The hulls of metal flying boats are, in effect, nothing but monocoque fuselages with a heavy section on the bottom to withstand the shocks of landing on water. Of course the joints must be made water tight, and steps must be taken to prevent corrosion, particularly around salt water. Both of these facts present problems not encountered in the design of landplanes. The same thing applies to repairs and maintenance, which is further discussed under "HANDLING AND MAINTENANCE OF SEAPLANES."

High concentrated loads in monocoque structures are usually

METAL MONOCOQUE FUSELAGES
(continued)



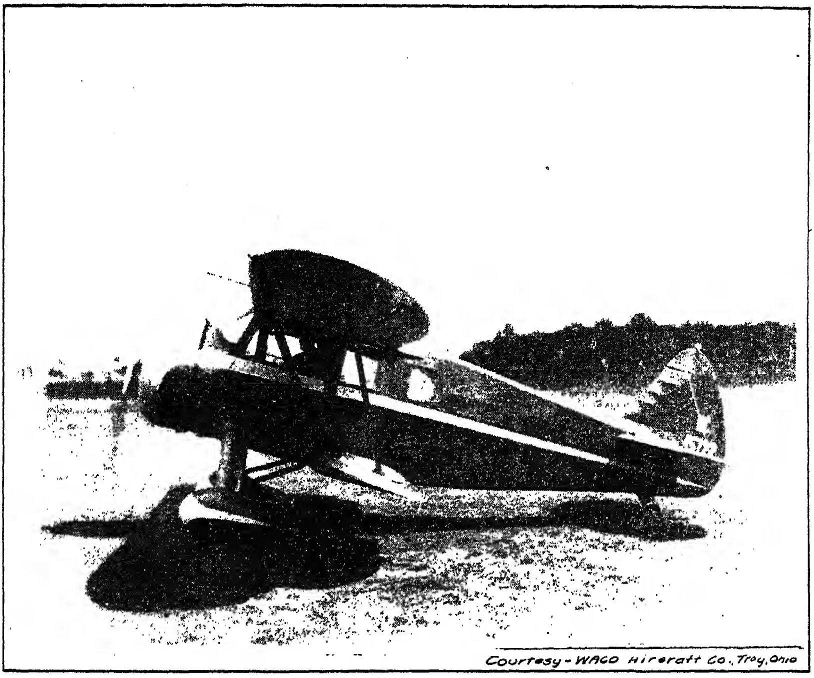
GRUMMAN ALL-METAL FIGHTERS

distributed by finger-plates which spread out over considerable area and make it possible for the comparatively thin skin to absorb the loads. Naturally, the bulkheads or formers are also made much heavier at such points.

In order to build or repair monocoque fuselages or metal-covered wings, the mechanic should be an expert riveter and should familiarize himself with the tools and methods described in the pages devoted to riveting.

The various shapes and sections of members are so numerous that it is impossible to illustrate them all. A number of examples showing both inside and outside are illustrated in these pages.

AIRCRAFT FABRIC WORK AND FINISHING

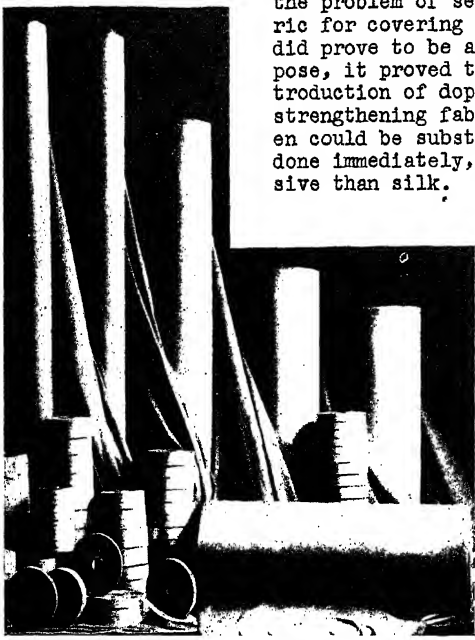


WACO CABIN AIRPLANE
An Example of a Modern, Fabric Covered Airplane

MATERIALS USED IN FABRIC COVERING

AIRCRAFT FABRICS

In many of the early experiments in heavier than air flight, wings were covered with silk, as this seemed to be the solution to the problem of securing a strong, light fabric for covering purposes. Although silk did prove to be a good fabric for this purpose, it proved too expensive. With the introduction of dope for tightening and strengthening fabric, it was found that linen could be substituted for silk. This was done immediately, as linen was less expensive than silk.



With the increasing quality of fabric dopes it was no longer necessary to use linen for it was found that cotton fabric could be strengthened sufficiently by the dope, to be used. As cotton is less expensive than either silk or linen, it has been adopted almost universally for airplane covering. There are still a few airplanes that use a linen cover, notably those of foreign manufacture.

Airplane fabric should be strong, light and absorbent. The strength and absorbability of cotton fabric is increased greatly by mercerizing. Mercerizing also greatly reduces the amount the fabric will stretch, which is also a decided advantage. It also reduces the moisture content of the fabric. As excess moisture is not desirable, airplane fabric should not be stored in a damp place.

The weight and the strength of fabrics are standardized to meet the minimum requirements of government regulations. The weight of airplane fabric is limited to 4.5 ounces per sq. yd. for most grades. The strength of fabric depends upon the number and type of thread used.

COMPARATIVE SPECIFICATIONS OF THE FABRICS LISTED

FABRIC NO.	THREADS PER INCH		STRENGTH PER INCH		WEIGHT PER SQ. YD.
	WARP	FILL	WARP	FILL	
No. 1155 Grade "A"	80	84	88 Lbs.	89 Lbs.	4.0 Oz.
No. 1123 Light Airplane	114	116	50 Lbs.	40 Lbs.	2.6 Oz.
No. 1124 Glider	96	100	45 Lbs.	36 Lbs.	2.7 Oz.
No. 380 Balloon	125	150	50 Lbs.	47 Lbs.	1.9 Oz.
No. 1080 Super Balloon	123	128	43 Lbs.	45 Lbs.	2.0 Oz.
No. 1403 Utility	68	70	56 Lbs.	50 Lbs.	4.3 Oz.

MATERIALS USED IN FABRIC COVERING (continued)

Modern wing fabrics use a 60 strand, two-ply yarn, both in the lengthwise threads, called warp, and in the cross threads, called woof, or filling. The minimum thread count is 80 threads in each direction. The strength of fabric should be at least 80 lbs. per inch in both directions.

The threads or yarns used in aircraft fabric are specially processed to remove the fuzz and nap. This results in a smooth cloth that is uniformly free from any fuzziness. This is an important asset to producing a smooth finish. As the absorbent qualities of the fabric must be considered, no starch or sizing is used in the weaving.

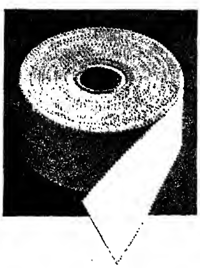
The standard widths used are 36", 42", 60" and 69". The 36" width is the most popular size. For special jobs, fabric can be ordered in almost any width. Fabric is graded as to its weight, its strength and number of threads. Grade A fabric is for use on all airplanes, however many of the light one and two-passenger airplanes use a lighter fabric called "light airplane fabric". Utility fabric is not used for airplane covers, but is suitable for linings, dust covers, etc.

FABRIC TAPE (WING TAPE)

Fabric tape, or wing tape, as it is popularly called, is a narrow fabric tape that is doped to the covering for the purpose of covering the stitches, and as a reinforcement. It is made of the same material as the airplane fabric and must meet the same government standard. Wing tape is furnished in 100 yard rolls, with the standard widths of 1-1/4", 1-1/2", 2", 2-1/4", 3" and 3-3/4". The most universally used width at present is the 2-1/4" width, however the narrower types are gaining in popularity.

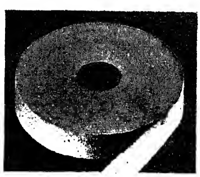
The edges of wing tape are usually pinked to prevent the threads ravelling. Pinked edges also simplify the job of getting these edges to stick tightly to the fabric. A selvage edged tape is not used, due to the difficulty in getting the edges of the tape to stick tightly to the cover. Tape with selvage edges would also be likely to bunch when stretched around a curve, such as on a wing tip.

PINKED EDGE TAPES



Another type of wing tape is sold under the trade name of "Sealedge Tape". It is a standard tape which has smooth cut edges and is sealed by a patented process, to prevent ravelling. Many prefer the appearance of the straight edged tape to that of the pinked tape.

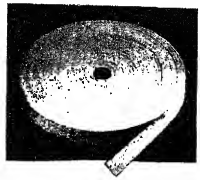
SEALEDGE TAPES



MATERIALS USED IN FABRIC COVERING
(continued)

REINFORCING TAPE

Reinforcing tape is a strong, heavy tape used for reinforcing and binding. It is supplied in 36 yard and 50 yard rolls of widths ranging from 1/4" to 1-1/4". Probably the greatest use for this tape is as a reinforcement under rib lacing. This heavy tape prevents the rib stitching, or lacing, from tearing through the fabric. Reinforcing tape is also widely used for rib cross-bracing and in binding parts into place. There are two popular types of reinforcing tape; the Army and Navy specification tape, and the commercial grade, herringbone tape. The A-N specification tape is an exceptionally strong tape, having heavy warp threads. It is used on military and large commercial airplanes. The commercial grade tape is a lighter tape, usually of herringbone weave.



Reinforcing Tape

THREADS AND CORDS

There are three main classifications of threads used in fabric covering; rib stitching, or rib lacing cord, machine sewing thread, and hand sewing thread. Each of these threads must meet the minimum requirements of government standards.

Rib stitching thread is a heavy cotton or linen cord, ranging in tensile strength from 35 lbs. to 300 lbs. It is used for lacing fabric covers to ribs, and for lacing covers around fuselage openings. For rib lacing, the lighter grade of cord is used, usually either the Army specification cotton cord or the Navy specification linen cord. The cotton rib cord is braided of 16 three-ply cotton strands and is thoroughly impregnated with wax. The braiding and waxing results in an almost fray-proof cord. When this cord is used, no further waxing is necessary. This is also sold in a five-ply cord.

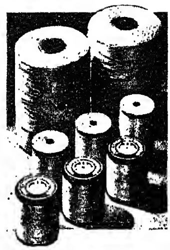
Cotton Rib Cord

The Navy specification linen cord is a left twist, nine strand unbleached cord. It is made of Irish flax and is not waxed. The linen cord used for rib lacing is usually of about 50 lbs. tensile strength. It is also supplied in #16, #20, #24 and #28, ranging in strength from 160 lbs. for the #16, to 300 lbs. for #28. These heavier cords are used for fuselage lacing and side openings in the fuselage.

Thread used for machine sewing grade A fabric is a left twist unbleached cotton thread. It is a four-ply thread of a size from number 16 to 20, having a tensile strength of approximately 4 or 5 lbs. The left twist is necessary, as many sewing machines have a

MATERIALS USED IN FABRIC COVERING
(continued)

tendency to untwist a right hand twist. Machine sewing thread is used to make machine sewed seams in fabric.



A-N Specification Sewing Threads

Hand sewing thread of the correct grade should be used wherever it is necessary to sew fabric covers by hand, such as on the trailing edge of a wing, control surface, etc. Either cotton or linen thread may be used. If cotton is used it should be an unbleached left twist, 4 strand number 8 thread. Linen thread should be an unbleached left twist, number 30, three strand thread. Each of these threads has a tensile strength of approximately 9 lbs.

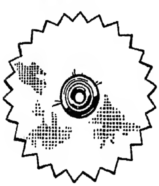
BEESWAX

All rib stitching thread and hand sewing thread should be coated with beeswax before using, as the beeswax preserves the thread and also prevents it fraying. Waxing also assists in hand sewing, as the thread has less tendency to twist while sewing. Beeswax is applied by pulling the thread over a cake of beeswax several times.

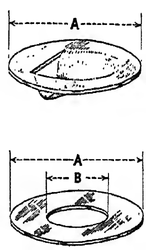
COVERING ACCESSORIES

Grommets are used to provide drainage and ventilation to covered surfaces. They are usually doped to the under surface of the fabric at its lowest point, such as the trailing edges of wings, control surfaces, etc. The earlier type grommets were made of brass fastened into a small pinked edge fabric patch. This patch was doped to the surface at the same time the second coat of clear dope was applied. It was then finished the same as the rest of the surface and the hole punched through the fabric when the job was completed. A somewhat neater and more convenient grommet to use is the celluloid grommet. They are furnished in two types; the plain washer type, and the suction type. Being made of celluloid, they can be readily applied to any doped surface, as they will adhere to wet dope. The suction type grommet is especially efficient for seaplanes, as it not only drains the wing faster, but causes a forced circulation inside the wing, which dries it out quickly.

BRASS DRAIN GROMMETS
Set in Fabric



Celluloid Drain Grommets



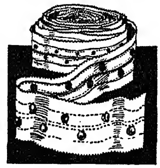
LACING TAPE

Many times it is desirable to remove and replace a large section of a fabric cover, such as where gas tanks are placed inside

MATERIALS USED IN FABRIC COVERING
(continued)

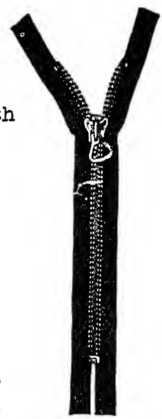
a wing. This may be done without having to recover the entire section, by using lacing tape so that the cover which has been removed may be laced back into place. Lacing tape is usually made by fastening standard hooks or eyelets to wide fabric tape, as shown. The lacing tape is doped to the fabric with the second coat of clear dope, and finished with the rest of the cover. When it is necessary to open the cover, the lacing tape is slit down the middle between the two rows of hooks or eyelets. A very sharp knife or razor blade should be used for this purpose. After the necessary inspection or repair has been completed, the section removed may be laced tightly into place, using a heavy number 28 linen cord.

LACING TAPE
With Hooks or Eyelets



SLIDE FASTENERS

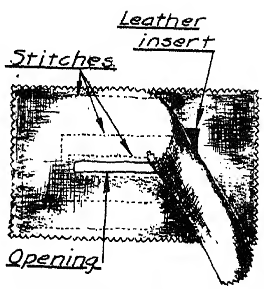
For small inspection holes in fabric, slide fasteners of the type shown are very often used in place of lacing tape. The fabric on the fastener is sewed to a fabric tape and is doped to the surface. The metal parts of the fastener should be covered with masking tape or heavy masking paste, otherwise the dope will prevent the fastener sliding. Care should be taken when applying these fasteners to allow for the fabric tightening, or it may be impossible to close the hole once it has been opened.



CHAFE PATCHES

Chafe patches are used to protect the fabric from abuse where it is likely to become worn by the movement of some part such as a control wire or a stabilizer strut. They are made by sewing a piece of soft leather between two fabric patches, as shown below. When replacing chafe patches, great care must be taken to make the new patch exactly the same size and shape as the original and to dope it to the cover so that there will be no strain on the cover when the control wire or strut is moved. After the patch has been doped in place, any loose fabric that extends beyond the chafe patch opening should be trimmed away carefully with a razor blade. The entire patch should be given the standard dope finish used on the rest of the cover.

The illustrations of fabric covering materials were furnished through the courtesy of Air Associates, Inc., Roosevelt Field, New York.



Chafe Patch

INSPECTION BEFORE COVERING

One of the greatest "crimes" of an airplane mechanic is to cover up a mistake. This holds true in any phase of mechanical work but especially so in covering the fuselage, wings and control surfaces. Before any covering is done, a most rigid inspection of the parts must be made, for after these parts are covered, their condition must be taken for granted. The damage that may be caused by loose or unsafetied wires, insecurely fastened controls, loose or naked electrical connections, can be left to your own imagination.

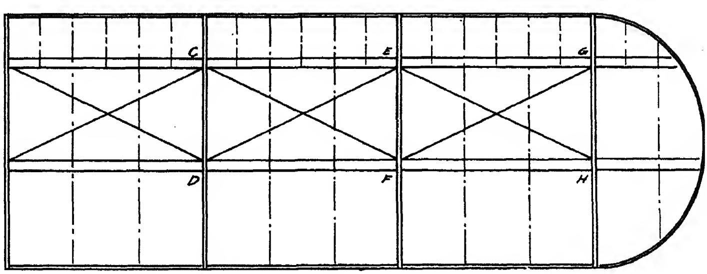
Wings should be systematically inspected before covering, for the following items: Alignment, controls, fittings, installation of accessories, bonding, protection and safeties.

CHECKING THE WING ALIGNMENT

In a great majority of the airplanes built today, the conventional two spar construction is used in the wing. These spars, whether metal or wood, must be absolutely straight in order to develop their full strength. In addition to the spars being straight, the wing as a whole must be aligned so that the ribs form the correct angle to the spars.

Except in the cases of tapered wings or wings having sweepback, all the ribs and the compression ribs or members are to be at right angles to the spars, Fig. I. The compression members are so arranged that the bays are perfect squares or rectangles. The trueness of the bay may therefore be checked by measuring the diagonal distances of each individual bay to see if they are the same. The length of the diagonal distances in inches is not important, as the main purpose is to find out if they are the same, for this reason a trammel bar is used. Note: The trammel bar is illustrated and described under "Sheet Metal Layouts".

Many wings are supplied with trammeling points on the top or bottom of the spars at each station. If such is the case the wing may be checked for alignment by placing one trammel point on the center point at station A (Fig. I) and adjusting the trammel so that the second trammel point rests exactly on point D. This measurement is then held and transferred to the points B and C. If



Three Bay

INSPECTION BEFORE COVERING
(continued)

the distances check exactly the first bay is square. If the distances are not the same the bay is not square and should be corrected. For instance, if the distance from A to D is greater than the distance from B to C, loosen the wire B-C and tighten the wire A-D a corresponding amount. Check the result with the trammel and if correct, re-safety the wires. This procedure should be repeated on each bay. Always start at the inside or root bay and work toward the tip. After the job is complete, check your work by sighting down each spar to see that it is straight.

If no trammel points are on the spars, the wing may be checked by holding one trammel point on the center of a fitting bolt head at station A and the second point on a fitting bolt head at station D. Transfer this measurement to the corresponding bolt heads at the stations B and C. Caution:- This method is not as accurate as when trammel center points are given, and for this reason great care must be taken to select points that are in main fittings and to use the exactly corresponding point on the opposite station.

CHECKING CONTROLS

All portions of the aileron control system that are inside of the wing must be thoroughly inspected to see that they are in a safe, workable condition. If control cable is used, the cable itself should be inspected for any broken strands or rusty spots. All control wire terminals must be tight and correctly served. Great care should be taken to prevent control wires from chafing against each other or any other object such as a fitting, rib diagonal, etc. The wires should have the proper protective coating of grease or suitable protective paint. All connections in the control system should be fastened with cotter pinned bolts and not clevis pins.

Control sheaves, or pulleys, should be checked for free turning and lubrication. The bearings should be clean and free from any spray dust, varnish, etc. The flanges of all sheaves should be inspected to make sure that no corners are broken off. Sheave guards should be free enough to permit the easy operation of the sheave, and close enough to prevent the control wire from jumping the sheave. If the sheave is of the ball bearing type which can be lubricated from the outside, make sure that the passage for the lubrication is clear. The entire assembly must be securely fastened in place.

If the wing is to be covered with the control wires in it, the excess wire which will extend beyond the wing when the job is complete, should be coiled neatly and fastened with a string to some stationary member near the wire exit. An inspection or hand hole is usually made so that the control wire can be threaded through the cover after the doping is completed. Coiling the excess wire is important as it lessens the danger of the wire jumping a sheave or getting tangled around a fitting or bolt head.

Wings that are covered before the control wire is installed should be provided with a strong heavy cord, running through the wing, the same as would the wire. This is called a fish, or snake

INSPECTION BEFORE COVERING
(continued)

line and is for the purpose of pulling the control wire through. It is just as important that the snake lines are not crossed as it is the control wire.

Control wire guides should be inspected to see that they are not too worn, or that they do not bind the wire.

The push-pull tube control system probably requires less time for inspection but it is, of course, just as important. The tube itself should be free from any dents and bends, and properly protected with no sign of rust or corrosion showing. The bell-cranks should be inspected for free action and unobstructed throw. Make sure that the entire system is securely bolted and safetied. Make sure that all parts that cannot be connected from the outside are in place.

FITTINGS

All fittings should be checked to see that they are firmly and securely bolted in place. They may be inspected further for cracks, elongated holes and proper protection.

INSTALLATION OF ACCESSORIES

Modern airplanes are including more and more accessories in the wings. It would be impractical to attempt to describe all the points to be checked in the installation of all the various accessories, such as landing lights, navigation lights, air temperature indicators, pitot tubes, de-icers, retractable light controls, flares, gas tanks, air brake controls, etc. The good mechanic realizes the importance of inspecting each and every accessory installation to make sure that it is in a safe, reliable, working condition. However, special attention should be paid to all electrical connections to see that they are secure mechanically and electrically. All plumbing lines must be tight and protected from chafing. Proper provision must be made to connect all accessories after the wing has been covered.

BONDING

Electrical bonds should be inspected to make sure that they are all in place and that some "link" has not been omitted. They should be protected from corrosion and breakage from vibration.

PROTECTION

Wood wing structures are protected by varnish. The most important thing to remember in checking this protective coating is to look in out of the way places, such as under a sidewalk section, inside of the nose fairing or around any replacement work. These are the places that are most likely to have been overlooked.

All drag wires should be held apart where they cross. This is done with a fiber block or a small pad of friction tape.

INSPECTION BEFORE COVERING
(continued)

SAFETIES

After a wing is covered, it may be as long as two or three years before it is fully inspected again, and for this reason it is essential that every part be safetied to prevent it from becoming loosened from vibration. Bolts should be safetied with castellated nuts and cotter pins, and studs should be safetied with safety wire. Clevis pins are cotter pinned. As a good safety precaution, all machine screws and bolts that are safetied with lock washers, can be further safetied by daubing a little gasket shellac on the exposed threads.

All turnbuckles must be inspected to see that not more than three threads are exposed and that the wire safety is in place and that the ends are securely fastened by at least four wraps. Tie rod terminals must be inspected to see that the rod is in sufficiently, by sticking a small wire through the inspection hole. Jam nuts must be tignt.

CHECKING CONTROL SURFACES

Control surfaces are comparatively simple to inspect before covering, as many sections have no internal accessories or moving parts. In general, the procedure outlined for wing inspection should be followed, where applicable.

CHECKING FUSELAGE

Before a fuselage is covered it should be inspected by someone who is thoroughly familiar with all the important points of the particular fuselage. The special points to be checked include all external connections, landing gear assemblies, all assemblies that are underneath the floor boards, all lines that are behind the upholstery, tubes, wires, controls, etc. that are in the tail section. In short, all parts that are not accessible after the cover is in place.

If the foregoing discussion on wing inspection seems quite exhaustive, remember that all of these items, even though extremely important, can be thoroughly checked in a short time. It is a job that no conscientious mechanic overlooks.

PREPARING FOR FABRIC COVERING

Before any structure can be covered with fabric, certain preparations for the fabric must be made. The preparations are made to insure three things; the proper protection to the fabric, the protection of the material from the dope, by dope-proofing, and to provide fastenings for the fabric where needed.

FABRIC PROTECTION

The fabric should be protected against any sharp corners or edges that would have a tendency to cut or wear a hole in the finished cover. These places will be found where sheet metal is fastened to wood, such as the edges of a metal nose fairing, or a metal trailing edge strip. If there appears to be any likelihood of a sharp edge at any point like this, the metal should be hammered down or filed smooth. Further protection is assured by covering the edge with a strip of wide reinforcing tape or adhesive tape.

Any nails, screws, cotter pins, rivets, etc., that extend above the fabric surface should be corrected to avoid tearing the fabric. Where it is necessary for some part, such as the end of a tube, to be in contact with the fabric, the portion should be covered with a soft leather pad to prevent chafing.

Although it takes a little time, it is a good practice to run your hand over every rib, stringer, etc. that will be in direct contact with the fabric, to make sure that no sharp corners exist.

DOPE PROOFING

Dope proofing is the term applied to protecting the structural materials from the effects of the dope. It also serves another purpose, that of preventing the dope from sticking the fabric to the structure. Most structural parts are protected against the corrosive effects of moisture with several coatings of varnish, in the case of wood, and enamel or lacquer in the case of metal parts. Dope will eat through varnish and lacquer, destroying the protection, therefore provision must be made to prevent the dope from coming in contact with either. Dope will blend with, or form a bond with, lacquers or other similar pyroxylin base paints. For this reason dope, as it penetrates the fabric, would cause the fabric to adhere to lacquered surfaces. This also is undesirable and must be avoided.

Dope proofing is done in several ways. Probably the most popular method is to cover all surfaces that are to come in contact with the fabric, such as longerons, spars, ribs, etc., with a dope proof paint. Dope proof paint is a paint of neutral base, which is neither cut by dope nor will it unite with dope. It is applied with a small brush over the protective undercoat. One coat only is needed in most cases, and more than is absolutely necessary is not desirable.

Another method of protecting undercoating from the lifting effect of dope is to cover these parts with a cellulose tape.

PREPARING FOR FABRIC COVERING
(continued)

This is a transparent tape, much similar to cellophane. It is furnished in rolls of widths varying from 3/4" to 3", the smaller widths being used for ribs, and the wider tape for longerons, nose fairings, trailing edges, spars, etc.

CELLULOSE TAPE

tape is applied by laying the tape over the undercoat and rubbing it down with a soft, dry cloth. It will stick immediately. This tape, being transparent, allows the inspection for corrosion (on metal parts) without removing the dope proofing.

Metal foil is sometimes used for dope proofing. This method consists of sticking very thin metal foil over the parts to be dope proofed. The foil is usually of aluminum, although other metals such as tin, etc. have been used. Metal foil is usually held in place by rubbing it into "tacky" varnish, or varnish that is not quite dry.

FASTENING FABRIC

Fastenings for the fabric do not have to be provided, as a rule, when covering wings and control surfaces, as the fabric covers the entire panel and can be securely fastened by sewing it together. However, in special cases such as where a large opening has to be left for a fitting or an inspection plate, some form of backing must be provided to hold the fabric. This is usually done with spruce or balsa wood frames built around the outline of the desired opening.

FABRIC COVERING

Before the actual work of covering can be started, the necessary material should be on hand so that the covering may proceed without interruptions. This is essential to a good job, as a structure that has been covered with fabric should be doped as soon as possible, preferably the same day, to prevent the fabric sagging. After the fabric has received its first coat of dope, the following steps of applying the wing tape, lacing tape, the necessary patches and the successive coats of dope, should follow immediately.

In many instances, covering is done in some locality where a supply of dope and fabric is not on hand. This material must then be ordered. For this reason it is essential that the mechanic know how to estimate the quantity of these materials that will be needed.

ESTIMATING MATERIAL NEEDED

Correctly estimating the amount of fabric needed to cover a given structure is more involved than simply finding the area of the surfaces to be covered and allowing a certain percentage for seams, cutting etc. For instance, if the estimate is for the fabric needed to cover a fuselage, it is necessary to know the correct widths to order. If the fabric is too wide, much material may be wasted in scrap pieces. Where fabric too narrow is used, more seams will be required, and may result in a finished job looking "patched".

In ordering material to re-cover a fuselage, it is always advisable to measure the widths of the original fabric and order the same. In the majority of cases, this procedure is much more desirable than attempting to use the narrower widths such as are used for wing covers.

The standard 36" width of fabric is usually used for covering wings and control sections. As with the fuselage, the original width of fabric should be used in all but special cases. Regardless of the width of the fabric needed, the procedure of measuring for the quantity needed is the same.

MEASURING FOR FABRIC

A straight wing may be measured for fabric very easily, as follows: Stretch a flexible steel tape around one of the form ribs, starting from the trailing edge, running over the rib and back to the trailing edge. If the rib is concave at any point, the tape should be held into this concave by an assistant. To this measurement add at least 4" for a seam. This gives you the camber measurement of the wing.

Next measure the overall length of the wing. To this measurement add one half the depth of the butt rib and in addition at least 6" for seams. To find the amount of fabric required to cover this wing, subtract 1" from the width of the fabric to be used (allowance for machine sewed seam), and divide this number into the overall length. For instance, if the fabric width is 36" and the overall length of the wing, including seam allowance is 150",divide

FABRIC COVERING
(continued)

35 into 150, which gives 4 with 10 over. This means that four full widths will be needed, plus 10" of another width, therefore 5 widths will be needed.

Multiply the camber length by the number of widths needed. If the camber length is expressed in yards, the result of the multiplication will be the number of linear yards of fabric needed. As an example, if the camber length is 3-2/3 yards, and 5 widths are needed, the total linear yards needed would be 18-1/3 yards.

Regardless of how accurate your estimations may be it is often advisable to order from 5% to 10% extra to allow for any mistakes, spoilage, waste, etc. This is especially true when ordering from a distant point as the few yards of extra fabric may cost considerably less than the delay caused by re-ordering.

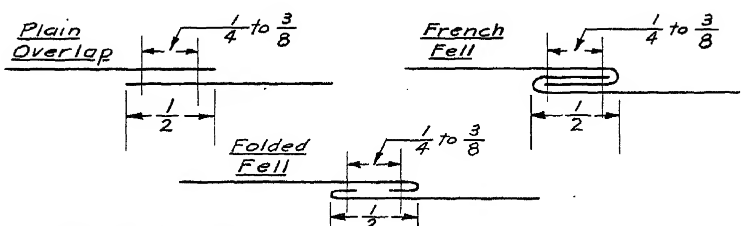
Wing tapes and reinforcing tapes are usually estimated by measuring the length of the taped seams and then ordering a generous surplus, as it costs little compared to the inconvenience that a shortage may cause.

Estimating the quantity of dope needed for a certain job is largely a matter of experience and familiarity with the doping methods used. Some helpful figures on the covering capacity of dope may be found on the pages devoted to "Dope".

MACHINE SEWED SEAMS

All structures should be covered so that the warp of the fabric (the lengthwise threads) run parallel to the line of flight. This necessitates sewing the fabric strips together along their selvage edge. Any standard type of sewing machine may be used to sew fabric seams, but as two lines of stitching must be made on seams, a double stitch sewing machine is preferable.

There are three types of seams that are accepted; the flat seam, the folded fell and the French fell, as shown in Fig. I. The French fell seam is to be preferred as it is somewhat stronger and does not expose the selvage edges. However, it is more difficult to make than the flat seam. The flat seam is used considerably on light commercial airplanes. All seams should be overlapped a distance of 1/2" and the lines of stitching should be about 1/16" from each edge or about 1/4" to 3/8" apart. The machine should be set to sew from



Machine Seams Fig. I

FABRIC COVERING
(continued)

8 to 10 stitches per inch, using the standard machine sewing thread as described under "Fabric Materials".

SLIP COVERS

A slip cover is one that is machine sewed to fit a structure. An opening is left so that the cover may be slipped over the structure and the opening sewed by hand. The advantages of this method of covering are that much of the tedious hand sewing is eliminated and if the slip cover is properly made, much time is saved. Ready sewed slip covers may be purchased for many types of airplanes. Slip covers cannot be used to advantage on structures that have several extended parts or protruding fittings. Probably the greatest disadvantage of the slip cover is the possibility of wasting material and time if the cover is made too small.

THE BLANKET COVER

Covering by the blanket method consists simply of placing the material over the structure as one large sheet or blanket and sewing it in place entirely by hand. This method, although somewhat slower, is a safer method as the possibility of wasted material is less.

MAKING THE COVER

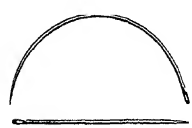
The best, safest, and quickest method for the inexperienced mechanic to follow in making a cover is first, to pin it in place. Then if a slip cover is to be made, the fabric may be marked with a lead pencil along the desired seam. After the fabric is marked it may be removed and machine sewed, using a flat single stitch seam, along the pencil lines. The excess material may then be cut off, leaving at least 3/4" to 1" excess.

After the slip cover has been completed, turn it inside out, so that the excess material is on the inside, and slip it over the structure. The open end may be "tacked" into place at 10" or 12" intervals, with hand sewing. The cover is completed by sewing the remaining seam with the baseball or roll stitch.

If the blanket method is used, the cover is pinned in place and the excess fabric cut off, leaving at least one inch to be turned under before sewing.

HAND SEWING

Hand sewing is done with either a straight or a curved needle, Fig. II, using the hand sewing thread described under "Fabric Materials". The stitches used are the baseball stitch and the roll stitch, Fig. III. In hand sewing there should be at least 4 and preferably 6 stitches to the inch and the stitching should be locked once in every foot.



Sewing Needles
Fig. II

FABRIC COVERING
(continued)

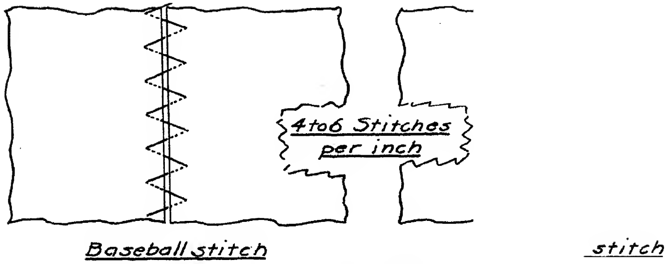


Fig. III

REINFORCING TAPE

Reinforcing tape of the same width as the cap strip of the rib should be placed around each rib on top of the fabric. It is usually started at the trailing edge and run around the rib and back to the trailing edge, where it is pinned together. It should be stretched sufficiently taut to remain in place, but not enough to put any undue strain on the tape.

RIB STITCHING (LACING)

Before the cover is doped, it is rib stitched, or laced to the ribs, Fig. IV. This is done to hold the cover to the form of the ribs, and to prevent the fabric chafing on the ribs. Rib stitching also reinforces the ribs by preventing their twisting.

Rib stitching is done with a long straight needle of sufficient length to allow it to be passed through the wing. The rib stitching needle is usually from 8" to 20" long. The thread used is described under "Fabric Materials".

When the airplane is in flight there is a negative pressure or suction on the fabric of the upper camber. This would pull the fabric away from the ribs if it were not held by the rib stitching. As the speed increases the pull on the fabric also increases and for this reason fast airplanes require a more firmly laced

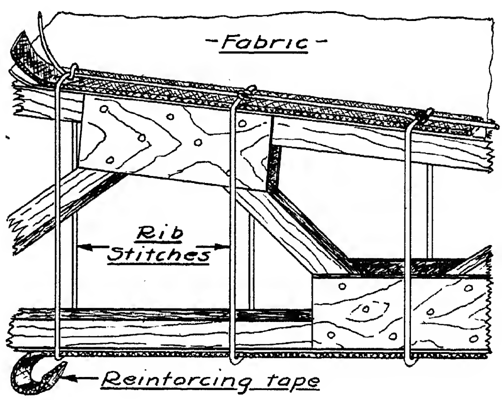


Fig. IV

FABRIC COVERING
(continued)

cover than does a slower ship. The table in Fig. V shows the correct spacing for the rib stitching for various speeds.

Speed in M.P.H.	Spacing of Rib Stitches
Up to 150	5 Inches
175	4-1/4 Inches
200	3-1/2 Inches
225	2-1/2 Inches
250	1-3/4 Inches
275 and over	1 Inch

Fig. V

Rib stitching is done by starting the sewing with a slip knot, Fig. VI. The stitchings are started at the leading edge of the rib and are continued in the correct spacing to the trailing edge. If the leading edge is covered with a nose fairing, the stitches start immediately behind the nose fairing. It is essential that each stitch be free from any slack. To prevent the possibility of the rib cord chafing through or breaking at one point, causing several stitches to be loosened, each stitch must be secured or locked with a seine knot. Seine knots are made by first making a half hitch, then sliding the needle under the standing parts of the thread, as shown in Fig. VII. The rib stitching should be ended with a double lock knot and the loose end cut off short.

The knots should be made on the upper camber of the wing as a general rule, although on some light commercial biplanes the knots are made on the upper camber of the top wing and the lower camber of the lower wing in order to have the surfaces that are visible present a smoother finish. All rib lacing is covered with fabric tape.

OTHER TYPES OF RIB LACINGS

Wings that have an exceptionally thick section and in places

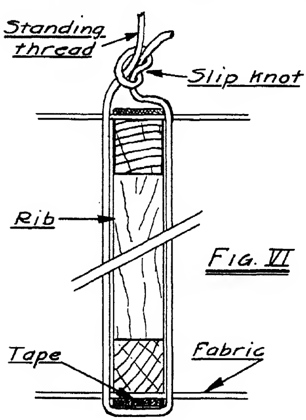


FIG. VI

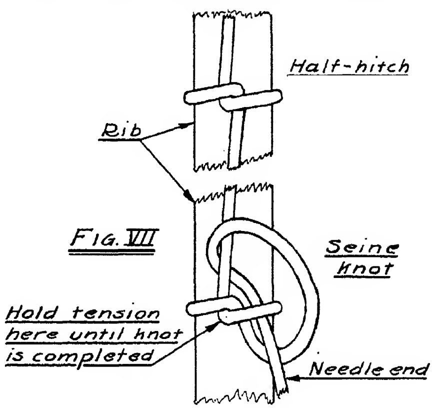


FIG. VII

FABRIC COVERING
(continued)

where it is impractical to pass a needle through the wing, the fabric is laced to each cap strip of the rib individually. As this method is much slower than the standard rib stitching it is not resorted to unless absolutely necessary.

This type of rib lacing is done with a 4" or 6" curved needle using the standard rib lacing cord. The stitch is made by starting the needle in the right hand side of the capstrip, passing it around the capstrip and out on the left side, at the location for the next stitch. The thread is then pulled through sufficiently to allow the needle to be started back through the same hole. It is pushed into this hole and is made to emerge on the left hand side of the cap strip, directly opposite the first hole, Fig. IX. This is done because it is impossible to get the stitching close to the cap strip by passing the curved needle directly from the right to the left side of the capstrip. This procedure results in the cord being around the cap strip at the correct location. The standard half-hitches and seine knot are used in securing the cord.

There has been considerable experimentation with various types of fastenings as a substitute for rib lacing, such as metal clips, flat head metal screws, metal ribbons, etc. So far no means have been devised which promise to replace the rib stitching.

REINFORCING PATCHES

All openings in the fabric such as for protruding fittings, inspection holes, etc. should be reinforced with fabric patches. These patches should be of sufficient size to be of value, and although no set figure can be given for their size, they are usually large enough to extend at least 2" beyond any cut or opening. They are cut to a snug fit and for appearance sake they are usually a definitely square, rectangular, oval or circular shape.

The edges of the patch should be pinked or frayed at least 3/16" so that they will stick tightly to the cover. Reinforcing patches are doped in place after the first coat of dope has been applied to the fabric and are then finished as a part of the cover.

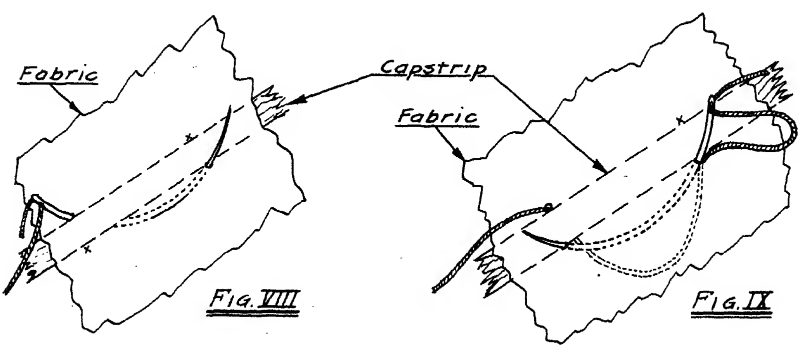


FIG. VIII FIG. IX

DOPE

Dope is a heavy liquid solution that is applied to fabric covers for the purposes of shrinking, waterproofing and preserving the fabric. It may be applied to the fabric either with a brush or with a spray gun. There are many kinds of airplane dope, manufactured by several different companies. For this reason it is impractical to state the exact composition of dope. In general the constituents of dope are classified as to the film base compound, namely cellulose nitrate or cellulose acetate.

NITRATE DOPE

Nitrate dope has a film base of cellulose nitrate, to which is added a flexilizer, solvents, thinners and slow driers. Flexilizers are used to produce a more flexible film, to prevent the hardening and cracking of the nitrate film base. Among the various types of flexilizers used are castor oil, camphor, triphenyl phospate, triacetin, etc.

The solvents, or the solutions used to dissolve and amalgamate the base and the flexilizers, are usually one or more of the following: Acetone, ethyl acetate and methyl acetate. Other solvents are used but they are usually some form of acetate.

The thinners used in dope to reduce it to the correct consistency for applying to the fabric are usually some form of alcohol, either ethyl or butyl alcohol. Many other forms of mineral spirits may also be used.

Slow driers, or anti-blush reducers are usually added to the dope when needed to prevent the dope from "blushing". Various forms of alcohol, cellosolve, etc. are used for this purpose. The use of reducers will be dealt with more thoroughly under the application of dope.

ACETATE DOPE

Acetate dope has a film base of cellulose acetates, which is its main point of difference from nitrate dope. It is more fireproof than nitrate dope and for that reason is sometimes used for the finish coats on a cover. Acetate dope is used very little in airplane covering, except as the finish coats.

USES OF DOPE

The main purpose of dope is to shrink the fabric to produce a cover of drum-like tautness. A tight cover is essential to securing and holding the airfoil curve of the form ribs. The dope also strengthens the fabric and preserves it so that the cover is able to withstand heavy air loads over a long period of time.

The application of several coats of dope to fabric produces an almost waterproof and airproof surface. The surface closely resembles a thin sheet of celluloid. The use of dope should be limited to fabric only. It is not suitable as a substitute for varnish on wood or as a substitute for clear lacquer on metal.

DOPE
(continued)

CLEAR DOPE

Clear dope is a transparent, although slightly opaque, solution that is used for the under coatings on the fabric cover. For applying with a brush it is about the consistency of syrup. It should be thinned with a nitrate thinner for use in a spray gun.

PIGMENTED DOPE

In the earlier experiments with fabric covered wings, clear dope only was used on the cover. While this produced a strong, taut cover, it did not exclude the ultra-violet rays of the sun, which were found to be very detrimental to the strength of the dope and the fabric, as well as harmful to the protective coating on the internal wing structure. To overcome this and to add to the attractiveness of the airplane, the wings were painted. Various types of enamels and lacquers were experimented with and the completed job protected by one or two coats of clear varnish. This method proved quite unsatisfactory, due to the necessity of removing all varnish and enamel before a patch could be doped to the cover, or before the cover could be given another coat to tighten it after some time of service. Another difficulty was experienced with various types of enamels as they would harden and crack or cause rings to appear.

The practice of enameling, varnishing or lacquering fabric covers has almost disappeared. This is due to the introduction of pigmented dope.

Pigmented dope is essentially a solution of clear dope to which has been added finely ground particles of pigment. The pigment is so thoroughly mixed into the clear dope that these inert particles are held in suspension. However, if pigmented dope is allowed to stand for some time, much of the pigment will settle to the bottom.

SEMI-PIGMENTED DOPE

The semi-pigmented dope is a dope that contains less of the pigment particles than does the pigmented dope. It is designed to be applied directly to the fabric without the preliminary coats of clear dope. In this manner the color is built up from the first coat. This dope cannot be used on any surface where a two-color scheme is desired.

COVERING CAPABILITIES

Due to the absorbability of the fabric the first few coats of dope applied cover less area than the later coats. For this reason it is difficult to give any satisfactory figures on the covering capacity of dope. However, as a general average, one gallon of clear nitrate dope will cover approximately 100 to 125 sq. ft. Pigmented dopes cover about 200 sq. ft. per gallon. Semi-pigmented dope will cover about 110 sq. ft. per gallon. The addition of thinner to any of the dopes greatly increases the covering capacity, but of course results in a thinner coating of dope.

DOPE
(continued)

For purposes of estimating the total quantity of dope needed for a given surface, it may be considered that one gallon of dope will cover about three square yards, where a regular nine-coat system is to be used. Of this about 60% will be of pigmented dope, while 40% will be of the clear dope. At least 25% additional should be allowed for thinner and anti-blush reducer. These figures will vary considerably, depending on the kind of dope used, the method of application, the amount and kind of thinner used, the number of coats, etc.

WEIGHT OF DOPE

Nitrate dope weighs approximately 7 pounds per gallon. Pigmented dope weighs approximately 7.5 pounds per gallon. The total weight of the dope film on a finished fabric is, for a regular nine-coat finish, about .06 pounds per square foot.

The table shown below was furnished through the courtesy of Berry Brothers, Inc., Detroit, Mich. It shows the film weight and the total weight in pounds per square foot of each coat of dope applied to fabric. It is understood that these figures will vary slightly as do the methods and conditions.

Weights of Dope Films in Fabric Finishes

No. of Coat	Material	Weight of Film	Total Weight in Pounds Per Sq. Foot
1st ONLY	Clear Nitrate Dope, Brushed	.0033	.0033
2nd ONLY	Clear Nitrate Dope, Brushed	.0047	.0080
3rd ONLY	Clear Nitrate Dope, Sprayed	.0046	.0126
4th ONLY	Clear Nitrate Dope, Sprayed	.0063	.0189
5th ONLY	Pigmented Aluminum, Sprayed	.0110	.0299
6th ONLY	Pigmented Aluminum, Sprayed, Sanded	.0023	.0322
7th ONLY	Color Pigmented, Sprayed	.0062	.0384
8th ONLY	Color Pigmented, Sprayed	.0103	.0487
9th ONLY	Color Pigmented, Sprayed, Rubbed	.0113	.0600
Regular 9-coat system.			
For 11-coat system, first 8 coats same as above.			
9th ONLY	Color Pigmented, Spray—Sand	.0065	.0552
10th ONLY	Color Pigmented, Spray	.0059	.0611
11th ONLY	Color Pigmented, Spray—Rubbed	.0062	.0673

Weight of Flightex Fabric, bare, .0281 pounds per square foot.

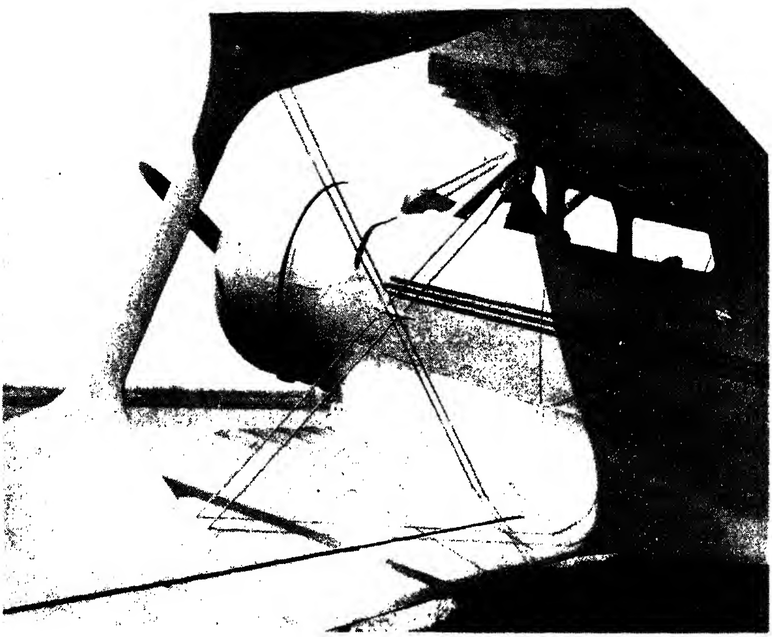
STANDARD DOPE FINISHES

There are two standard dope finishes; the pigmented dope finish, and the semi-pigmented dope finish. There are, of course, many variations of each but in general the methods of application do not vary greatly. Regardless of which type of finish is to be used the first coat of dope should be applied as soon as possible after the cover is completed, preferably the same day, to prevent the fabric taking a permanent sag.

PIGMENTED DOPE FINISH

The pigmented dope finish is probably the most popular method used in commercial airplane coverings. It ranges from a nine coat to a twenty coat finish. It is usually either a nine coat or an eleven coat standard. Although the pigmented dope finish is somewhat heavier than the semi-pigmented dope finish, a smoother finish which will retain a higher polish is obtained when using the pigmented dope. The various coats required to make a regular eleven coat pigmented dope finish are given below.

The first coat is clear nitrate dope and as it is desirable to have a heavy first coat, it is usually applied full-bodied, or unthinned, with a brush. It should be applied freely, but not rubbed



An Example of Pigmented Dope Finishing 225 HP Jacobs BEECHCRAFT

STANDARD DOPE FINISHES
(continued)

into the fabric. Where the weather conditions make it necessary the first coat may be thinned up to 15% with a good grade of thinner or reducer. The first coat of dope should be allowed to dry at least thirty minutes.

The second coat is also clear nitrate dope and should be applied immediately after all wing tape, reinforcing patches, grommets, lacing tapes, etc. have been doped into place. See "Application of Tapes and Patches." The second coat may also be applied with a brush and may be thinned up to 15% if necessary. This coat should be allowed to dry for at least one hour. If time permits, overnight drying would be advantageous. After this coat has dried sufficiently it should be sanded thoroughly to remove any runs or high spots, using #000 sandpaper. This sandpaper should be used dry and care should be taken not to exert too much pressure on the fabric.

The third coat of clear dope is usually applied with a spray gun, however, if spray equipment is not available the entire finish may be brushed. It is very difficult to obtain a perfectly smooth finish with a brush. For this reason the third coat and all succeeding coats should be applied with a spray gun if possible. If this coat is applied with a brush it should be thinned between 10% and 15%. If a spray gun is used it may be applied full-bodied, or it may be thinned up to 15%. It should be allowed to dry at least thirty minutes.

The fourth coat of clear dope should be applied in the same manner as the third coat and it should be allowed to dry thirty minutes.

The fifth coat of dope should be applied the same as the third and fourth coats, but allowed a minimum of four hours for drying. Longer drying is desirable, if possible. The fifth coat of clear dope should be dry sanded with #000 sandpaper so that the surface is perfectly smooth.

The sixth coat of dope serves as a base for the desired pigmented color. The standard color for this base is aluminum, however if the finish is to be red a base color of yellow or orange pigmented dope is to be preferred. For dark maroon and dark blue finishes, a black base is used. After the color for the base has been selected it should be sprayed on the cover full-bodied or thinned up to 15% and allowed to dry for forty-five minutes.

The seventh coat of dope is also a base coat and is applied as was the sixth coat. It should be allowed to dry for at least six hours. This completes the base coatings and the surface should now be carefully water sanded, using #280 wet-or-dry sandpaper. The surface should be washed thoroughly with clean water and wiped dry with a clean chamois.

The eighth coat should be pigmented dope of the desired finished color and may be thinned or reduced from 20% to 50%. It

STANDARD DOPE FINISHES
(continued)

should be allowed to dry for at least forty-five minutes.

The ninth coat of dope is applied as was the eighth coat and it should be allowed to dry for four hours. After this, it may be lightly water sanded with #320 wet-or-dry sandpaper.

The tenth coat of dope should be applied as coats number eight and nine, and allowed to dry for at least forty-five minutes.

The eleventh and last coat of dope should be applied very carefully to avoid any possible runs, holidays, high spots, etc. It should be thinned from 30% to 50% with a good grade of thinner or anti-blush reducer. It should be allowed to dry for eighteen hours before it is sanded smooth, using #400 wet-or-dry sandpaper. The sandpaper should be constantly lubricated with water.

After the surface has been sanded smooth it may be hand rubbed to a high gloss, using rubbing compound. The entire finish should be protected with wax or polish.

SEMI-PIGMENTED FINISH

The semi-pigmented dope finish is made by using a dope which has less pigment than the pigmented dope. Where this method is used it is not necessary to use clear dope for the undercoats. This type of finish is used almost exclusively at present by the U. S. Army Air Corps. The standard semi-pigmented dope finish consists of from five to nine coats of dope, usually either five or seven coats. As the five coat finish is probably the most popular, it will be described below.

The first coat is applied full-bodied with a brush and is allowed to dry one hour. The second coat is applied immediately after the wing tape and fabric accessories have been doped into place. This coat should be allowed to dry for four hours, and then sanded smooth, using #000 sandpaper. The third coat of dope may also be applied with a brush and given at least one hour in which to dry.

The fourth and fifth coats of dope may be thinned from 25% to 50% and applied with a spray gun. The fourth coat should be allowed to dry at least four hours if it is to be sanded before the fifth coat is applied. The finish is now complete and may be protected by spraying a coat of clear gloss dope. After eighteen hours of drying the surface may be waxed or polished.

THE APPLICATION OF DOPE

The success of dope finishes depend upon many things including the method of application, the temperature, the humidity, the correct mixture of anti-blush reducers and thinners, the sanding, etc. In addition to the special methods necessary in the application of dope, further precautions are required in the handling, storage and the use of dope as it is highly inflammable and its fumes are harmful if breathed in excess. To insure the best and safest results, doping is usually done in a special dope room where many of these factors can be controlled.

Before the methods of dope application can be discussed, some of the common troubles encountered in doping should be mentioned, together with their causes and prevention. The following discussion on this subject is taken directly from the book "Specifications for Aircraft Finishing" by one of the largest manufacturers of aircraft dope in America, the Berry Brothers, Inc., of Detroit, Mich.

"(1) In cold weather, dopes left in unheated rooms or outside become quite viscous. These should be kept in a warm room between 75-80° at least 24 hours before using - when in 50 gallon drums, it will take the dope 48 hours to reach this temperature. Cold dopes will pull and rope under the brush, and if thinned sufficiently to spray or brush, will needlessly use extra thinner and lack "body" when the thinner evaporates.

"(2) 'Blushing' in dopes or lacquers is common in humid weather. This condition in nitrocellulose products is caused by rapid evaporation of thinners and solvents, which lowers the temperature on the surface, causing condensation of moisture in the atmosphere. This moisture on the surface of the wet dope or lacquer precipitates the nitrocellulose out of solution, thus giving the white appearance known as 'blush'. Of course such a decomposed finish is of no value either in tautening or protecting the surface for any period of time. Therefore, the blush must be eliminated if the finish is to endure. This is best accomplished by spraying the blushed surface with a mixture of Berryloid Reducer and Berryloid Anti-Blush Reducer in approximately equal parts, depending on the degree of blushing. If badly 'blushed', a greater proportion of Anti-Blush Reducer is required, or less when slightly 'blushed'. Berryloid Anti-Blush Reducer can also be successfully added to the lacquer or dope to assist in prevention of 'blush' during application.

"Remembering the old motto - 'An ounce of prevention is worth a pound of cure', we feel it wise to include herewith some information on the best atmospheric conditions for a dope room and methods of 'blush' control.

"The best working conditions in a dope room are obtained at temperatures between 65-80° F., with a relative humidity not over 65% at these temperatures. Methods of humidity control are as follows:

"(a) Simple (Heat) Method - When the relative humidity is only high enough to cause a small amount of blushing, an increase of 5°

THE APPLICATION OF DOPE
(continued)

or 10° F. in the room temperature will generally stop the trouble. This method is limited in its scope because temperatures over 90-95° F. cause too rapid drying of dopes - a common cause of pinholes in the finish.

"(b) Mechanical Method - This is by far the best method of humidity control, as it is possible by the use of proper equipment to produce any desired atmospheric condition. This is accomplished by the use of refrigeration and heating equipment, wherein moisture is removed from the air by cooling (refrigeration) to a sufficiently low temperature and the low humidity air then reheated to the proper temperature before passing into the room.

"The main drawback in the use of this type of equipment is the initial expense involved. (It is likely that local conditions may be such as to make it possible to reduce the cost by the elimination of part of the above process and its requisite equipment.)

"(c) Solvent Method - If the blushing troubles are not too severe (i.e., if the relative humidity and temperature are not in excess of 70% and 85° F.), it is possible to eliminate the difficulty by the addition of anti-blush reducer to the dopes and lacquers, in quantities not to exceed one quart of anti-blush reducer to one gallon of dope or lacquer.

"The disadvantages of this system are (1) increase in time required for finishing, due to slowing up of drying, and (2) cost of the anti-blush reducer.

"Many finishers of aircraft have found it possible to combine methods 'a' and 'c' to produce the desired result in a very economical fashion, without materially affecting production time.

"(3) 'Orange peel' or 'pebble' on a lacquer or pigmented dope finish will result from insufficiently reduced lacquer or pigmented dope, or when the spray gun is held too far from the surface to be painted. Cheap thinners tend to aggravate this trouble as well as reduce the lustre of the finish. Use only those thinners made and recommended by the manufacturer of the dope or lacquer.

"(4) 'Pin holes' in a lacquer or dope finish are caused by entrance into the spray gun of water or oil in the air line. Hence, air lines and air conditioning units should be kept clean and in first class condition at all times. 'Pin holes' and 'blisters' may also be caused by force drying of the lacquer or dope with heat.

"(5) Wet areas on a lacquered or doped surface indicate that oil, grease, wax, soap, etc., which may have been on the surface previous to lacquering or doping, had not been properly removed. Thorough cleaning of all parts to be painted must be insisted upon.

"(6) Lacquer or dope will 'blister' if applied in too heavy or too wet a coat over a priming coat which has not thoroughly dried. The only remedy is to clean off the surface and refinish.

THE APPLICATION OF DOPE
(continued)

"(7) Runs, sags, laps and streaks are caused by improperly ad- d spraying equipment or by improper application of material. Excess material will run before it has had a chance to dry. Streaks made by not thinning the material enough may be eliminated by cross spraying, i.e., spraying one coat horizontally and the next vertically. Laps will show if the last coat was insufficiently reduced. A coat of reducer consisting of one part Berryloid Anti-Blush Reducer and three parts regular Berryloid Reducer will remedy this trouble. Cross spraying is advised in using lacquers and pigmented dopes.

"(8) Peeling or flaking of a finish on metal parts results from improper undercoats of primer or improper treatment of the surface. The metal should be mechanically roughed by sand blast, wire brushing, or hand sanding, as paint will not properly adhere to a glassy dural or aluminum surface or to scaly steel tubes or fittings. After the above operation, clean with Deoxidine and wash off with warm water and dry, leaving a virgin, neutralized surface of metal ready for the prime coat. If possible, use oil base metal primers and bake on at suitable temperatures; otherwise, air dry. Pyroxylin primers do not check incipient corrosion, and are more subject to peeling than are high grade oil base primers.

"(9) Refinishing troubles are varied and many. So many types of materials and methods of application have been used that it seems impossible to specify a system of refinishing over old fabric that will always give satisfactory results. In the first place, most ships are finished at the factory in the maximum number of coats that it is desirable to apply to the fabric, and addi condly, the weathering of the c

"If the paint job is badly cracked and the fabric two years old, the Department of Commerce inspectors generally demand recovering.

"Oftentimes the old dope and paint can be partially removed with Wax Free Paint and Dope Remover, and built up again with additional coats. Remember, the old surfaces should first of all be cleaned with high test gasoline, or benzol, and at least softened up with a solvent such as above mentioned. It is generally advisable to refinish a small surface or section at first, and if satisfactory, complete the whole job in the method that gives the painter best results.

"What might be a very serious trouble is fire; so preventives of such disasters deserve serious consideration. Fire hazards in aircraft factories can be practically eliminated by observing the following precautions:

1. Use 'good housekeeping' methods throughout the entire plant.
   a. Spontaneous combustion will occur in piles of dirty or oily rags. Remember that many fires start this way, as well as

THE APPLICATION OF DOPE
(continued)

from paint materials.
- b. Dirt and spray dust on the floors, spraying equipment or in spray booth is a source of danger. Keep your equipment clean at all times.
- c. Do not allow an excess of paint, dope or lacquer to accumulate in any form (dry, dust or semi-dry) in or near the finishing department.

2. Proper ventilation is necessary both in spray booths and dope rooms.
   - a. Exhaust fans of sufficient size should be installed in spray booths. Non-sparking equipment should be used.
   - b. The fresh air supply should be distributed to avoid back drafts from exhaust chambers.
   - c. Keep windows closed near spray booths and admit air through designated openings generally along the ceiling.
   - d. Reputable manufacturers of spraying equipment should be consulted on this important subject.

3. Spraying work outside of properly designed spray booths constitutes a serious hazard with all types of finishing materials. Immediate exhaustion of fumes from spraying or doping operations eliminates one of the greatest hazards of dope or lacquer.

4. All painting and doping materials not in actual use should be stored well outside of the finishing buildings.

5. No smoking should be permitted in aircraft factories, nor should open flames be allowed near the finishing rooms.

6. Fire-fighting equipment should be readily available.
   - a. An overhead sprinkling system will pay for itself in a few years in savings on fire insurance.
   - b. Fire extinguishers of the foamite type are recommended for the paint department.

7. 'Ground' the mechanical equipment in the paint shop to prevent sparks of static electricity.

8. Concrete floors in finishing rooms are not recommended because of sparking caused by workers' shoes. Composition flooring or rubber soles on workers' shoes will eliminate this danger.

9. When possible, separate the dope and paint rooms from the rest of the factory, preferably in another building. "

BRUSHING DOPE

It is with the first two coats of dope that the nap of the fabric is set. For this reason it is usually considered better to brush the first two coats of clear dope on a cover rather than apply them with spray equipment. When dope is applied with a brush

THE APPLICATION OF DOPE
(continued)

it may be used full-bodied, thereby providing a heavier base or undercoatings. It is possible, of course, to apply all the coats with a brush and if it is done skillfully a taut, durable finish may be obtained. However, it is much easier to secure a finish that will take a high polish if spray equipment is used to apply the final coats.

If two or more coats of dope are to be applied with a brush, the coats should be cross-brushed; that is, one coat brushed lengthwise and the next coat brushed crosswise. As a general rule brushed coats should be allowed more time for drying than spray coats. The best results are obtained by using a semi-soft, long bristle brush. The brush should be of a good grade, which does not shed bristles, as these are very difficult to remove from wet dope. As doping is usually done on comparatively large surfaces the brush used is usually of a width from 4" to 6", or even larger. The use of a large brush reduces the time required for the job, and also lessens the likelihood of laps or streaks on the finish.

When doping with a brush no attempt should be made to cover the surface with a coat as thin as would be done if paint were being used. The entire surface should be brushed in one direction only, using a well filled brush. Care should be taken to brush away immediately any drops of dope that may have fallen from the brush or the dope pot, on either the undoped fabric or the surface already covered. Heavy drops of dope will have a tendency to blush and sometimes will cause a permanent high spot. It is much easier to remove this excess dope immediately than it is to attempt to sand it smooth after it has dried.

When in use the dope brush should be kept free from any gummy deposits of dope, such as usually accumulate near the base of the brush. Dope brushes should never be allowed to stand over ten or fifteen minutes without having first been thoroughly cleaned with thinner or reducer. A brush that has been used for anything except dope or lacquer should not be used for doping unless it is absolutely necessary, in which case it must be thoroughly cleaned with reducer to remove all possible oil and wax.

DOPING WING TAPE

Wing tape is usually applied after the first coat of clear dope has had sufficient time to dry. It is applied by doping the tape directly to the fabric in one of two methods. It may be applied as a separate operation before the second coat of dope is applied. If this method is used the section of the fabric where the wing tape is to be applied is first given a coat of dope with a brush, and the wing tape laid while the dope is still wet. The tape should be smoothed into the dope to remove any air bubbles and to insure a smooth finish. Immediately after it has been smoothed, the tape should be given a coat of dope.

Another method for applying wing tape is to use tape which has been saturated with dope and then allowed to dry. The procedure

THE APPLICATION OF DOPE
(continued)

for applying tape by this method is in general the same as is used for applying the undoped tape, the advantage being that less trouble is encountered in getting the tape to adhere tightly to the fabric.

APPLYING ACCESSORIES

Accessories such as reinforcing patches, chafing patches, lacing tapes, slide fasteners and grommets set in fabric, are doped to the cover in the same manner as wing tape. Celluloid grommets are also attached before the second coat of dope has been applied, although many times they are attached by simply pressing them down on the fabric while the second coat of dope is still wet.

SANDING DOPED SURFACES

Where it is desirable to produce a smooth, highly polished finish the surface should be sanded smooth between coats, as outlined in "Finishing Methods". In no case should sandpaper coarser than No. 000 be used to sand a doped surface. Great care should be taken not to exert too great a pressure while sanding, as this will cause the fabric to stretch or sag. It is also likely to cut through the dope film and into the fabric. As the finish of the surface nears its completion, the grade of sandpaper used should be much finer. This is essential in producing a smooth finish, free from scratches. To further preclude the possibilities of scratching the finish, a water sandpaper (wet-or-dry) is used. This sandpaper has a waterproof backing which allows the paper to be kept wet while in use, the water preventing the sandpaper scratching the finish. Note: Only clean water should be used when wet sanding a surface. Avoid the use of gasoline or thinner when sanding a wing.

SPRAYING DOPE

The use of spray equipment for the application of dope has become almost universal. For this reason it is essential that the airplane mechanic be familiar with spray equipment and its use. The spray equipment itself is described on the pages entitled "Spray Equipment".

Probably the greatest single factor contributing to successful spray doping is clean equipment. There must be no hardened dope or paint in the spray gun or nozzle. There must be no oil, grease, dirt, water, or any foreign particles in the dope, hose lines, or spray gun. Before using spray equipment, each part should be checked to see that it is perfectly clean. The spray gun nozzle should be washed in clean reducer to remove any hardened dope. If the air holes in the spray nozzle are clogged, they should be cleaned with a match stick, broom straw or other soft material so as not to damage the nozzle.

For spraying dope the best results are obtained by using a pressure pot, as it is possible to spray heavier bodied material using this type equipment than it is using the suction cup spray

THE APPLICATION OF DOPE
(continued)

gun. If the suction cup spray gun is used the dope may have to be thinned from 40 to 50% to be sprayed.

In spraying large surfaces such as wings, fuselage covers, etc. it is desirable to have jigs so arranged as to allow the surface to be held in a vertical position. The bottom edge of the surface should be at least 12" above the floor to eliminate the possibility of the blast from the gun blowing any dirt or dust on the wet surface. Suitable arrangements should be made so that the strokes may continue uninterrupted from the top of the surface to the bottom, and on the alternate coats, from one end to the other.

If the surface to be sprayed has been standing for any appreciable time the surface should be air dusted before the dope is applied. Most spray guns are so arranged that when the trigger is pulled half way back, a stream of air and no dope will be thrown from the nozzle. This may be used to clean the surface of any accumulated dirt or dust. If a regular air duster is available, this of course should be used.

The spray gun should be adjusted so that it throws a full bodied spray, about 12" in width, when held about 8" from the surface. The gun should be kept at a uniform distance from the surface during the entire stroke. While as a general rule this distance is from 6" to 8", it should be governed by the results obtained. If the material being sprayed has a tendency to run, the gun is either set to spray too much material or it is being held too close, or it is being moved too slowly. Runs are often due to the dope having been thinned too much. If the material being sprayed has the appearance of dust it shows that it is drying before reaching the surface. The gun is being held too far away. This effect may also be caused by moving the gun too rapidly, or by not having sufficient thinner in the dope.

It is imperative that the gun be in motion at all times when the material is being sprayed. If the stroke has to be interrupted the spraying must be stopped before the gun, as a run will surely result if the gun is held stationary, or in one place even instantaneously. To avoid the stroke being interrupted or made unevenly, the hose lines should be held in one hand, allowing sufficient slack in the line to permit the gun to be moved freely with the other hand.

It is not usually a good practice to attempt to remove a run while the dope is wet. It is better to let it dry, as it sometimes disappears entirely while drying. If it does not, it may be sanded smooth before the next coat is applied. Small dope runs may be quickly dried by using the blast of air from the spray gun. Care should be taken, however, not to "blow" the run away, as this would cause the run to spread unevenly over a larger area. Care should also be taken not to pull the trigger too far back or more dope will be added to the run.

To avoid noticeable laps or streaks between strokes, each

THE APPLICATION OF DOPE
(continued)

stroke should overlap the preceding stroke about 2". Fluid to be sprayed should be strained through a cheese cloth or other similar material to remove any skin or lumps. Never thin material to be sprayed to a watery consistency. Material to be sprayed should be as thick and in some cases thicker than for hand brushing.

If considerable dope spraying is being done, a respirator should be worn to prevent breathing the dope fumes. It is a good practice to spend at least 10 or 15 minutes in the fresh air after each solid hour of doping. Spray doping should never be done in any insufficiently ventilated enclosure. Proper precautions should be taken to prevent any fires or explosions. Smoking in a dope room is of course strictly prohibited. A generous supply of adequate fire extinguishers must be ready for immediate use.

The use of masking tape in the spraying of two color finishes, license numbers on wings, etc., will be discussed under "Masking."

REPAIRING FABRIC COVERS

One of the advantages of a fabric cover is the ease with which it can be repaired. A section of fabric can be replaced with much less trouble than the same repair could be made on either a wood or metal skin. Small punctures and tears can be repaired by simply doping a small patch over the hole. Some of the various types of patches are described below.

Small holes or punctures such as might be caused by chafing or by the impact of sharp objects when landing or taxiing, etc., may be repaired by doping a small patch over the damaged area. There are no definite rules as to the size of the hole that may be repaired in this manner, the decision being left to the mechanic. However, in general, only damaged areas of less than 2" are repaired in this manner.

To repair a small hole, trim the edges of the damaged area so that no frayed or stretched fabric remains. If at all practicable, the hole should be trimmed to make a square or round opening. Remove the old dope from around the edges of the hole for a distance of about 3". This may be done by brushing either clear dope or thinner over the area and as soon as the old dope has been softened, usually within one or two minutes, scraping the original dope off the cover with a knife or razor blade. Ordinary paint remover should never be used to remove dope, for it leaves a residue of wax over which new dope cannot be applied successfully. A good type of wax-free paint remover can be used. Great care should be taken not to exert too much pressure when scraping, or the fabric near the edges of the hole will be stretched, making a neat patch impossible. If stretching does occur, it is best to cut away the stretched fabric even though a larger hole results. It is not necessary to attempt to remove all of the original dope, but at least <u>all</u> of the pigmented dope should be removed. Several softenings and scrapings may be required to do this. After sufficient dope has been removed the cleaned area should be smoothed with fine steel wool. Special care should be taken to make the cleaned area "fade" into the pigmented dope so that there

THE APPLICATION OF DOPE
(continued)

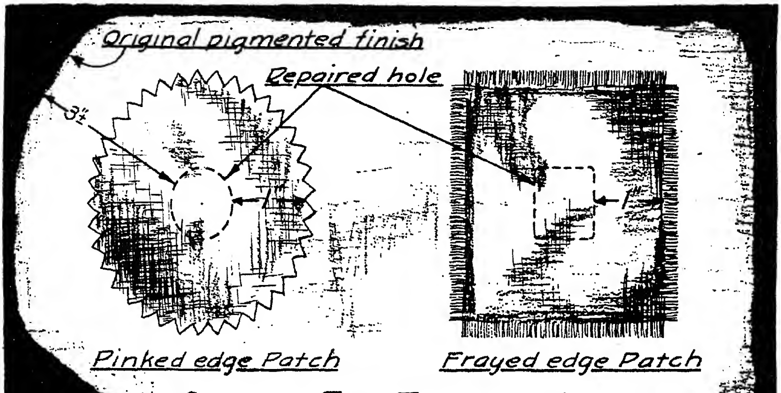


FIG. I

will be no sharp lines or "bumps" when the new finish is applied.

A fabric patch (of the same material as the original cover) should be made of sufficient size to extend at least 1" beyond the sides of the hole. The edges of the patch should be pinked with either a pinking machine or with pinking shears, Fig. I-A. If pinking shears are not available the edges of the patch should be frayed for a distance of about 3/16". Remember that the edges of only a square or rectangular patch can be frayed evenly. Note: The edges are pinked or frayed to prevent further raveling and to provide better adherance to the cover.

If a square or rectangular patch is used it should be put on so that it is square with the ribs or slipstream, so that it will have as unobtrusive an appearance as possible.

The patch may be applied to the cover by first giving the area prepared on the cover a coat of clear dope and while the dope is still wet, rub the patch into place and immediately give the portions of the patch that extend on the cover a coat of clear dope. After 15 or 20 minutes the edges of the patch should be given another coat of clear dope. After the edges of the patch are stuck firmly, the entire patch and the area cleaned should be built up to the original finish of the cover with the proper number of coats of clear dope and pitmented dope. The various coats should be smoothed by sanding as was done for the original finish.

Tears in the fabric cover may be repaired with a patch applied as described above, however if the tear is over 2" long it should be sewed before applying the patch. A curved needle is used to make

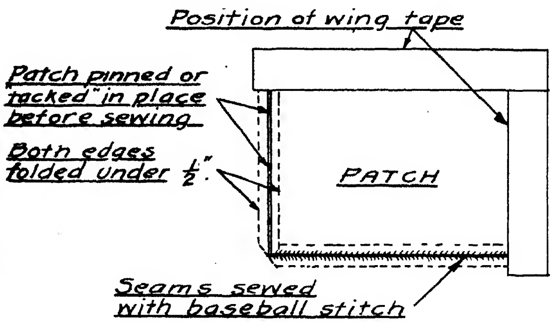
THE APPLICATION OF DOPE
(continued)

the standard baseball or roll stitch. If the damaged area is in the form of an L, T or X shaped tear, the stitches should begin at the ends of the tear and progress to the intersection. If the tears can be closed tightly with the sewing, wing tape may be used to cover the seams, otherwise a larger patch will have to be prepared.

A large damaged area should be repaired by sewing in a new piece of fabric and then covering the seams with wing tape. The damaged area should first be trimmed to a definite square or rectangle which is parallel to the ribs or slipstream (whichever presents a better appearance). The edges of the hole should be cleaned as described previously. Next, make a 45° cut in each corner of the hole so that the edges may be turned under for a distance of 1/2". A patch should be prepared large enough so that when each edge is folded under 1/2" it will just fill the hole left in the cover. The patch is now pinned in place and the folded edges sewed together, using a curved needle. The patch should be wrinkle-free and taut when the sewing is finished. Care should be taken, while sewing, not to "bunch" the fabric at the seam. If there is a tendency for the fabric to bunch, the excess material should be folded under the patch so that the finished seam will be flat.

The seams should be covered with wing tape and given three coats of clear dope before the entire area is doped. Naturally, the repaired area should be treated the same as a new cover as regards finish.

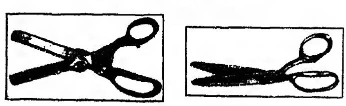
A damaged area where the fabric has been stretched but not broken, such as might be caused by a heavy blunt object falling on the surface, may be repaired by removing the dope from a generous area around the damage and, starting with clear dope, build the finish back to the original. This will nearly always retighten the area if the fabric is not too old.



or Panel Patch

FABRIC PINKING MACHINE

FABRIC PINKING SHEARS



SPRAY EQUIPMENT

Spray equipment consists of a spray gun driven by compressed air, which sprays fluid through an adjustable nozzle; suitable provision for supplying fluid to the gun; air transformers for regulating the amount of pressure and for removing oil and water from the air; and a source of compressed air. A typical installation is shown in Fig. III. This illustration does not, however, include a compressor for supplying compressed air. Such a compressor is shown in Fig. XVI. Equipment of this type is suitable for spraying dope as well as lacquers and enamels. A complete outfit suitable for lighter work is shown in Fig. II.

THE SPRAY GUN

There are many types of spray guns on the market, but for aircraft paints, lacquers and dopes a gun similar to the type shown in Fig. I is recommended. This particular type of gun with proper nozzle combination may be used with a suction feed cup, pressure feed cup, or with a pressure feed tank. The pressure feed tank, as illustrated in Fig. III, is especially desirable for production work in volume; saving frequent refillings of the fluid container. A pressure regulating device provides for uniform flow of either light or heavy bodied materials to the spray gun. A suction feed cup is for use in applying small quantities of light bodied materials, such as lacquer or enamel. The pressure feed cup can be used for heavy bodied materials when a small container is desirable.

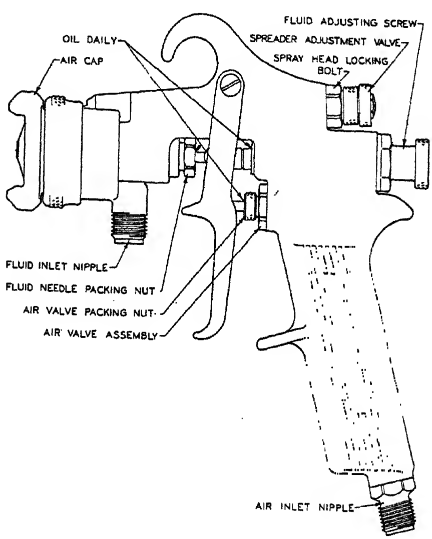


Fig. I

ration of Spray Gun - The following instructions apply specifically to the DeVilbiss spray gun illustrated in Fig. I, but in general they may be applied to other types as well.

Lubrication - Do not immerse gun in solvents - this destroys lubricants. Proper lubrication of the spray gun is essential to assure continued perfect operation. Lubricate daily all bearing surfaces and moving parts with a light oil. For points of lubrication see Fig. I. Fluid Needle Spring in fluid adjusting mechanism should be kept coated with a covering of light grease or vaseline. Fluid Needle and Air Valve Stem Packing should be removed occasionally and inspected. Keep packing soft by occasional lubrication.

SPRAY EQUIPMENT
(continued)

Adjustments - Fluid adjustment is made by regulation of Fluid Adjusting Screw (Fig. I.) Turn screw to the right to decrease the amount of fluid flow and to the left to increase it. Width of spray is controller by the Spreader Adjustment Valve. By turning valve to the right the width of spray is decreased and to the left it is increased. Variation of spray pattern from round to extremely wide is possible. The face of this valve is graduated permitting specific settings for the various spray patterns, shown in Fig. IV. With certain materials, too wide a spray adjustment will cause a "split" spray, i.e., the pattern becomes thin in the center and heavy at the ends. When this occurs, reduce the width of spray.

Care and Cleaning - Spray gun troubles are usually caused by neglect or improper cleaning, therefore the following items are especially important. Keep gun lubricated. Keep packing nuts around fluid needle and air valve stem tight. Do not tighten so securely that parts cannot move freely. Keep gun clean. It is not necessary to take spray gun apart to clean it. Spray clean solvent through gun and wash off outside with clean solvent. Do not use caustic alkaline solutions for cleaning as they destroy aluminum alloy. An unbalanced or distorted spray indicates a dirty air cap. Remove air cap and wash thoroughly in clean solvent. If reaming of air cap holes is necessary, use match stick, broom bristle or other soft implement. Never use a hard or sharp instrument for this purpose, as it may permanently damage the cap.

Do not remove spray gun parts unless absolutely necessary. When replacing air valve assembly make certain air valve spring is properly inserted in recess provided in gun body.

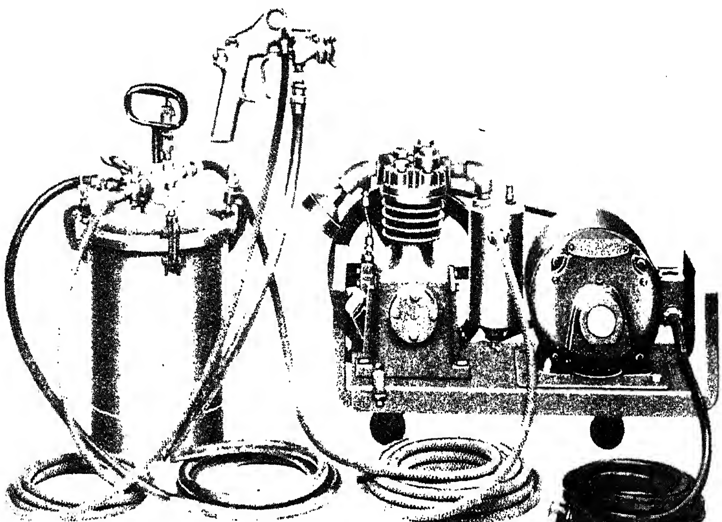
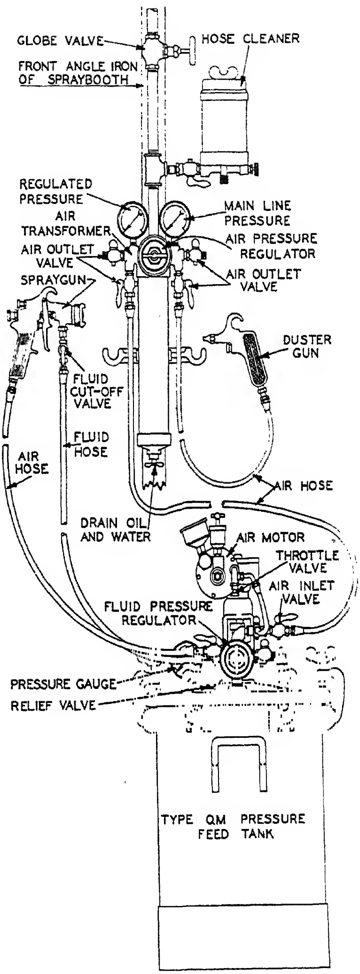


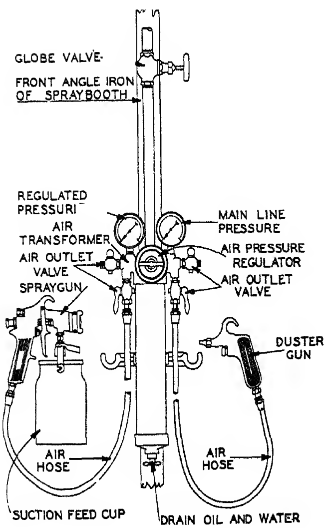
FIG. II PORTABLE SPRAY EQUIPMENT

SPRAY EQUIPMENT
(continued)

INSTALLATION OF SPRAY EQUIPMENT

FIG. III





SPRAY EQUIPMENT
(continued)

Fig. IV

Where only a small quantity of fluid is to be sprayed, or where the colors used are to be changed frequently, it is sometimes more desirable to use suction cup spray guns such as those illustrated in Figs. V and VI. In these the fluid is carried in a detachable cup directly below the gun.

The fluid cup has to be vented to allow the fluid to be removed. While in use this vent hole must be cleaned frequently to prevent its stoppage, which would cause an uneven or jerky spray. Type of material feed, air compressor capacity, working conditions, surfaces and materials vary considerably and require proper combination of air cap and fluid nozzle for maximum efficiency and highest quality finish. Be governed, therefore by the recommendations of the manufacturer of the spray gun.

PRESSURE FEED

Where any large amount of heavy bodied fluid is to be sprayed a pressure feed system is recommended. The pressure feed system uses a pressure feed tank as shown in Fig. VII. They are supplied in capacities from 2 gallons to 120 gallons. This eliminates the necessity of constantly refilling the fluid cup and also permits the use of a heavier fluid and produces a smoother spray. Pressure feed tanks are equipped with an agitator for stirring or agitating the fluid to prevent its settling. The agitators are operated with by hand or with an electric or compressed air motor. The installation of the pressure feed tank is shown in Fig. III.

Fig. V

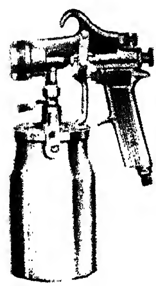
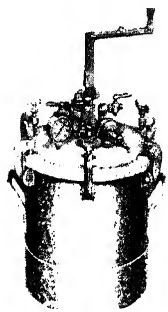


Fig. VI

HOSE

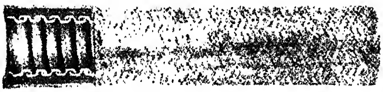
The hose used for conveying paints, lacquers and dopes must be constructed of a material which is not affected by the thinners and retarders used. It should be heavy enough to withstand hard usage and yet flexible enough to permit easy handling. Fig. VIII shows the construction of typical spray equipment hose. For extra heavy duty and rough handling, a flexible metal lined hose such as shown in Fig. IX is used. The average size of a fluid hose is 3/8" or 1/2" inside diameter. The fluid hose lines are designed for a working pressure of from 50 lbs. to 100 lbs. and have a minimum bursting pressure of from 500 to 800 lbs. An air hose such as the one illustrated in Fig. X is



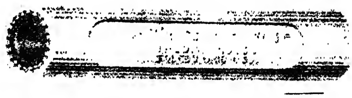
Pressure Feed Tank
Fig. VII

SPRAY EQUIPMENT
(continued)

Construction of Two-Braid Insert Hose Fig. VIII



Metal Lined Fluid Hose Fig. IX



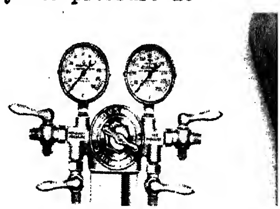
Air Hose Fig. X

made of pure gum rubber with braid inserts and a corrugated rubber cover for protection. The standard size for spray gun attachment is 1/4" or 5/16" inside diameter. They are designed for a working pressure of 125 lbs.

THE AIR TRANSFORMER

An air transformer of the type shown in Fig. XI is used to regulate the amount of air pressure to the spray gun and to clean the air. The air delivered to the transformer always contains some oil from the compressor and some water caused by condensation, and many times particles of dirt and dust.

Air transformers are equipped with a pressure valve and pressure regulating screw, similar to those used on welding regulators. This makes it possible to regulate exactly the pressure delivered to the spray gun and prevents any pressure fluctuations. The air must pass through a fabric sack or cleaner before it leaves the transformer. This cleaner is contained in the long cylinder part of the transformer. In some types of equipment this cleaner is a separate unit called a condenser. The cleaner should be removed and replaced by a fresh cleaner every two or three days, depending on the conditions. The transformer or condenser should be drained every few hours while in use.



Air Transformer
Fig. XI

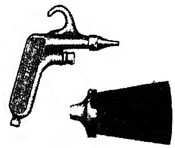
Air transformers are equipped with two gages. One gage shows the pressure on the main line while the other shows the pressure to the spray gun.

AIR DUSTERS

Air dusters of the type shown in Fig. XII are used to dust surfaces, preparatory to spraying. They are sometimes equipped with a brush attachment. Fig. III shows the installation.

SPRAY EQUIPMENT
(continued)

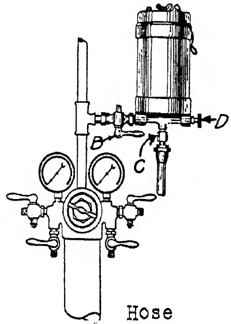
HOSE CLEANERS



Air Duster
Fig. XII

All fluid hose lines should be cleaned immediately after use. This is best done with the hose cleaner, Fig. XIII. After the spraying is finished remove the fluid hose from the spray gun and attach it to the hose cleaner at connection "C". Remove the lid on the pressure pot so that the fluid in the hose line may be blown back into the pot by opening valve "B". Caution: Make sure that all the pressure is released from the pressure pot before attempting to remove the lid.

After the fluid has been forced out of the hose line the needle valve "D" should be opened a few turns, allowing the reducers or solvents in the hose cleaner tank to be blown through the line. Note: If it is not desirable to have the solvent added to the fluid in the pressure pot, the lid should be removed entirely and the solvent caught in some suitable container. When the hose is clean, close the valve "D" and allow the air to dry the solvents. The valve "B" may then be closed.



Hose
Cleaner
Fig. XIII

RESPIRATORS

There are many types of respirators used, but in general their design is quite similar. They consist of a frame which holds a chemically treated filter pad. The respirator fits over the nose and mouth to prevent breathing the fumes and dust particles from the spraying process. A typical respirator is shown in Fig. XIV.

SOURCE OF COMPRESSED AIR

Respirator
Fig. XIV

Compressed air for running spray guns may be furnished direct from a compressor run by a small electric motor to the spray gun. This is a very inferior method, as much of the fluctuation of the air is transmitted to the spray gun. A much more satisfactory method is to have the compressor fill a storage tank and use the air from the tank. Without the proper volume and pressure of compressed air the spray gun cannot be expected to do its work efficiently or to apply the high grade finish it is capable of producing.

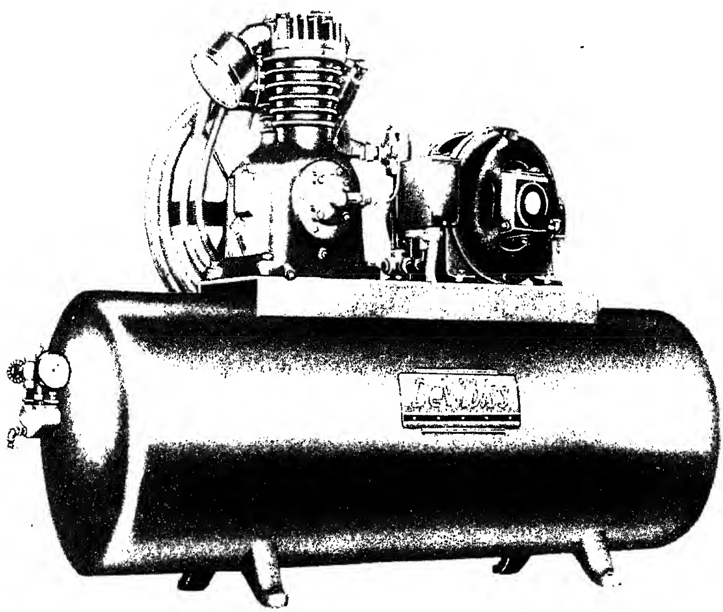
It is important, therefore, that in the selection of air compressing equipment, careful consideration be given to the factors of volume and pressure. The former is expressed in terms of cubic feet per minute and the latter in pounds pressure per square inch. The rated displacement of the compressor is not the actual volume of delivered air. Actual volume of delivered air is dependent upon the efficiency of the compressor. After determining the volume and pressure of compressed air required by your spray equipment, (figure on a minimum of 80 pounds pressure and a consumption of 10 cu.ft./min.

SPRAY EQUIPMENT
(continued)

for each standard production spray gun and 5 cu.ft./min. for each touch-up spray gun) be sure that your air compressor will actually deliver this volume of air at this pressure. Don't attempt to use a compressor that is too small. Make allowance for the requirement of other air operated equipment in the shop and for possible increased future demands for compressed air.

Locate the air compressor where it receives an abundance of cool, clean, dry air on a level foundation readily accessible for lubrication, service and draining of air tank. Compressor should be equipped with an efficient intake strainer that is easily cleaned or replaced and should be inspected periodically. Compressor air tank should be drained of water daily.

A typical heavy duty compressed air unit is shown in Fig. XV. The illustrations of spray equipment were furnished through one of the largest manufacturers of spray equipment in America, The DeVilbiss Co., of Toledo, Ohio.



HEAVY DUTY AIR COMPRESSOR UNIT

Fig. XV

MATERIALS USED IN AIRCRAFT FINISHING

For the purpose of definitely limiting the scope of this descriptive information, the term "aircraft finishing" will include only those finishes that may be applied by brushing, dipping or spray painting.

Aircraft finishes can be divided roughly into three classes according to their purposes: protection, appearance and decoration. Internal and unexposed parts are finished mainly for the purpose of protection. All surfaces that are exposed are finished to present a pleasing appearance as well as to provide protection. Decorative finishing includes the painting of signs, emblems, insignia, stripings, etc.

The materials used in aircraft finishing are too numerous to classify, however a few of the more important materials and their uses are described below.

VARNISH

Clear varnish is a slightly yellow, semi-transparent liquid of a resinous base. Its greatest use in aircraft work is the protection of wood structures. Only the best grade of spar varnish should be used for this purpose. If it is to be applied to bare wood the first coat should be thinned about 20% with turpentine. Varnish requires about 4 to 6 hours to dry dust free and from 24 to 48 hours to dry hard, although some good varnishes are now being put on the market that require a shorter time for drying.

Two or three coats of varnish are usually considered ample for woodwork protection and they may be applied either by brush or with a spray gun. Varnish is often used on interior cabin woodwork and trim to produce a durable high luster finish.

Varnish dries by oxidation. This means that the varnish has to be exposed directly to the air before it will dry. As an example, if varnish is allowed to stand in an open container, the varnish on the surface will oxidize, forming a hard scum or skin. This skin effectively prevents the air from reaching the varnish underneath. The portion of the varnish which has not been exposed to the air will remain in the liquid state for several weeks or months.

An excessively heavy coat of varnish will not dry correctly, often requiring several days or weeks to become hard and very often remaining gummy permanently. This is due to the outside or exposed surface of the film drying and forming a seal or protective skin, thus preventing the body of the coat oxidizing. Much better results will be obtained from several thin coats than from one heavy coat. This holds true of any material that dries by oxidation.

VARNISH STAIN

Varnish stain is clear varnish to which has been added a tar base stain. This material is used very little in aircraft work except for decorative trim. It is used to duplicate natural wood finishes such as mahogany, oak, cherry, etc. It is applied by brush

MATERIALS USED IN AIRCRAFT FINISHING (continued)

and requires usually about 4 hours for drying.

COLOR VARNISH

Color varnish is made by adding color pigment to a good grade of clear spar varnish. It is used for protection and the finish on metal and wood parts. It is preferred by many mechanics to enamel. Color varnish is also thinned with turpentine and has a drying time of from 4 to 24 hours. Generally speaking, the quick drying varnishes are not as durable as are the slow drying varnishes.

TURPENTINE

Turpentine is a colorless liquid refined from the resinous substance extracted from pine or fir trees. It is used as a thinner and quick-drier for varnishes, enamels and other rosin and oil base paints. Turpentine dries by evaporation. It is a solvent for these materials and therefore should be used to remove paint spots and to clean the brushes used.

FILLER (WOOD)

Filler is a composition for filling the pores of wood before using paint or varnish. It is usually in the form of a paste or a liquid. It is used on soft wood to add to the sealing power of the protective coats. On hard wood it is used to secure a smooth finish. The average paste filler requires no time for drying, whereas the liquid fillers usually require from 30 minutes to 4 hours.

"LIONOIL"

This is a proprietary article, but as it has such widespread use in the aircraft industry, it may be discussed here. It is a clear amber colored liquid, much similar in appearance to clear varnish. Its greatest use is for protective undercoats. It may be used successfully on all kinds of metals and woods. "Lionoil" has replaced varnish as a protection for wood to a considerable extent. It is used for the internal protection of steel tube structures and is applied by blowing the fluid through the structure with compressed air and then allowing it to drain out. Clear Lionoil may be cut or reduced with turpentine or naphtha. Note: Never use gasoline. Two to four hours are required for it to dry dust free and from 12 to 48 hours for it to set permanently.

OIL STAINS

Oil stains are thick tar base fluids used on bare wood to stain the fibers to represent more expensive wood colors. Oil stains are used in preference to varnish stains, as a rule, especially for surfaces which are large. They may be applied with a cloth or a brush and the excess stain wiped off immediately with a clean rag. If a deeper color is desired, let the stain remain for a few minutes before wiping off.

MATERIALS USED IN AIRCRAFT FINISHING (continued)

Varnish should not be applied over a stained surface until it has been allowed to dry for at least 4 to 6 hours.

ACID STAIN

Acid stain serves the same purpose as oil stain, but due to its constituents it will penetrate deeper and give a more permanent stain. The greatest use in aircraft work for acid stain is in refinishing stained surfaces, as it is much more effective in staining "filled" wood than is oil stain. Acid stain should never be used on structural parts.

ENAMELS

Enamel (as pertaining to its use in aircraft finishing) is a semi-transparent, opaque or colored liquid, used primarily for finishing metal parts. It can be either brushed or sprayed, full-bodied or thinned with turpentine.

There are many kinds of enamel on the market, many of which are not suitable for aircraft finishes. Some enamels dry so hard and brittle that they will crack and peel off when subjected to the vibration of the airplane. As a rule the slow drying enamels are more durable than the fast driers. Most enamels dry by oxidation.

Where an especially durable heat-resisting finish is required, such as on cylinders, crank cases, etc., a special enamel is brushed or sprayed on the surface and the object is then placed in an oven and the finish dried by baking. Baking enamels vary in their requirements, but the average time required is 2 hours at 220° F.

OIL PAINTS (PIGMENTED)

Oil paints can be secured in almost any color. They are supplied in paste form put up in tubes or jars. For decorative painting purposes such as insignia, emblems, etc., they are reduced with linseed oil and thinned with turpentine to the desired consistency.

Unreduced Prussian blue oil pigment has long been used as a protective coating for wires and cables, being applied with a soft brush or cloth. This practice has been almost entirely replaced by the use of patented grease compounds.

WATER PAINTS

The use of water soluble paints is quite limited. They are, of course, not suitable for protective coats and being water soluble can be easily washed off with water, therefore they cannot be used for a permanent finish. The greatest, if not the only, use of water paints is in the painting of temporary signs or numbers on the wings or the fuselage.

Water paints are usually supplied in powder form and are mixed to the proper consistency for brushing, with cold water.

MATERIALS USED IN AIRCRAFT FINISHING
(continued)

LACQUER (BRUSHING)

Brushing lacquer is a comparatively slow drying lacquer which may be applied with a brush. It is used largely for touch-up work on lacquered surfaces. It dries hard in about 4 hours, having the same characteristics as spraying lacquer. The greatest use of brushing lacquer is in decorative painting, such as striping, painting insignia, emblems, etc. on lacquered surfaces.

LACQUER (SPRAYING)

This lacquer is a quick drying liquid of a cellulose base. It is similar in its general characteristics to airplane dope. Clear lacquer is a transparent liquid used to secure a high gloss finish when applied over a lacquered or doped surface. It is also furnished in many standard airplane colors. It is affected by climatic conditions and is therefore subject to the various troubles experienced when applying dope (see "The Application of Dope") but to a lesser degree.

As its name implies, it is designed to be applied with a spray gun. It may have to be cut with thinner or reducer to the proper consistency for spraying. In an emergency this lacquer can be applied with a brush if sufficient anti-blush reducer is added. Ordinarily it dries dust free in from 5 to 15 minutes.

The greatest use of lacquer is in finishing metal structures, although it has been used with some degree of success on wood. Lacquer should never be used over an oil base paint or enamel, as the solvents in the lacquer cut the oil paints, loosening the entire film, which causes the finish to crack or peel.

All lacquers dry by evaporation. This means that it will dry without forming a scum or skin, making it possible to apply lacquer in heavy coats and still have it dry properly.

DOPE

While dope is designed primarily for fabric covers, pigmented dope can be used, with varying degrees of success, on primed metal and plywood surfaces. Description of dope will be found in the pages entitled "Dope".

SHELLAC

Shellac is a crude, resinous base liquid used for a sealing coat for the protection of wood. Its greatest use is for waterproofing wood non-structural members, such as upholstery frames, fairing stringers, etc. Shellac dries by evaporation in from 30 minutes to 4 hours, and may be thinned with alcohol.

BITUMINOUS PAINT

There are several grades of bituminous paints sold under var-

MATERIALS USED IN AIRCRAFT FINISHING (continued)

ious trade names. This is usually a heavy black paint of a tar base used for internal waterproofing such as on the interior of hulls and wood pontoons. It is also used as a bottom paint for hulls. It may be thinned or reduced with high test gasoline or naphtha. Bituminous paint mixed with an equal quantity of marine glue makes an excellent waterproofing material for metal and wood parts.

MARINE GLUE

Marine glue is a waterproof liquid glue. Strictly speaking it is not a painting material but has been used considerably for waterproofing structures, especially in seaplane construction. It may be applied with a brush. It does not become hard but dries dust free, retaining a great amount of elasticity. Marine glue is used also as a seal on float and hull repair gaskets and for a seal between planking.

PRIMER, OIL BASE

Oil base primer is, as its name signifies, an oil base primer used for priming or base coating wood or metal. It makes a suitable base for color varnishes, enamels or lacquers. It may be thinned with turpentine but naphtha is recommended, especially if the finish coats are to be of lacquer. The priming coat may be applied either by brush or spray gun; however it should never be thinned over 25%. Drying time required is from 12 to 24 hours. Much better results will be obtained from a thin coat of primer than from a heavy coat.

Where the equipment is available, a much better result may be obtained by baking the primer at 225° F. for 1-1/2 hours. A more elastic and adhesive primer can be made by mixing equal parts of Lionoil and oil base primer and baking in the same manner.

PRIMER, PYROXYLIN

Pyroxylin primer has a cellulose base much similar to lacquers. It dries quickly by evaporation, requiring only a few minutes to dry dust free. Due to its fast drying qualities it should be applied with a spray gun and may be cut with thinner or reducer. It is not recommended as a primer for steel surfaces as it does not afford the protection found in other types of primers. If used at all, it should be applied only in a thin coat and allowed at least four hours to harden permanently.

PRIMER, ZINC CHROMATE

Zinc chromate base primer is a semi-transparent greenish-yellow liquid that is widely recommended for priming coats on all metal surfaces, especially on aluminum and its alloys. It dries almost immediately and succeeding coats of lacquer, dope, enamels, etc., may be applied after 30 minutes. It is better, however, to allow from 6 to 12 hours for this primer to set. It may be applied by

MATERIALS USED IN AIRCRAFT FINISHING (continued)

brush, spray gun, or dipping. For spraying it should be reduced from 200% to 300% with toluol (toluene). The flexibility and durability of this primer may be improved by baking at 225° F. Note: This primer should never be baked at a heat in excess of 350° F.

LINSEED OIL

Linseed oil is a yellowish oil obtained from the seed of flax. It is used to reduce lead base paints. It is also used, applied hot, to soften wood for bending.

NAPHTHA

Naphtha is a clear, volatile, highly inflammable liquid product of coal tar, much similar to high test gasoline. It is used as a cleaner and as a reducer for various paints.

LACQUER THINNERS AND REDUCERS

The thinners and reducers used to cut lacquers are described under "Dope".

STEEL WOOL

Steel wool is sharp steel shavings or turnings. It is supplied in various grades of coarseness, and is used for cleaning and surfacing.

SANDPAPER

Sandpaper is used for cleaning and smoothing wood surfaces preparatory to finishing. Waterproof sandpaper is made of a waterproof paper to which has been glued an abrasive, usually a form of carborundum or emery. It may be used dry or lubricated with water or gasoline to prevent scratching. It is used to surface finishing coats. It is often called wet-or-dry sandpaper.

PAINT, VARNISH AND DOPE REMOVER

There are many grades of paint, varnish and dope removers on the market today. The majority of these removers have a base of acetone, mixed with a quantity of wax to prevent too rapid evaporation. Acetone "cuts" nearly every type of finish, or loosens it so that it may be more readily scraped off. As the presence of wax prevents dope or lacquer adhering to the surface, it is recommended that the remover used on surfaces to be refinished with either lacquer or dope, be free from wax.

RUBBING COMPOUND

Rubbing compound is a mildly abrasive, wax-free paste. It is usually used to surface the final coat on doped or lacquered surfaces to produce a high gloss finish.

RECOMMENDED AIRCRAFT FINISHES

There are many general types of finishes used on aircraft structures. Many of these types of finishes are special and are limited to certain structural parts and accessories. The standard aircraft finishes discussed below are generally recommended for aircraft work.

WOOD SPARS, RIBS AND SIMILAR STRUCTURES

Structural parts that are made of spruce are usually finished primarily for the protection of the wood itself. Wood of this kind should always be protected with a clear, transparent finish. A finish of this type is desirable, as it permits the inspection of the wood parts for cracks, checks, bruises and splits much more readily than if a color finish is used. For this reason structural wood parts should never be stained unless it is absolutely necessary to the finished appearance of the airplane.

One of the best and most widely recommended finishes for structural spruce parts is clear varnish, which is described under "Materials Used in Aircraft Finishing". Clear varnish may be applied directly to the bare wood, the first coat being thinned 20% with turpentine. It should be allowed to dry for at least 24 hours before the next coat is applied. Two coats of spar varnish are considered sufficient for protection and may be applied either with a brush or with a spray gun; however, if a spray gun is used it is recommended that three coats be given.

If facilities are available for dipping, a very durable and elastic finish may be obtained by applying one dip coat of clear "Lionoil", followed by one coat of clear spar varnish.

HIGH LUSTRE VARNISH FINISH FOR WOOD

If a high lustre finish is desired, such as is often used for paneling, cabin trim, plywood skin, etc., the surface should first be prepared by applying the desired stain or filler. Stains and fillers are described under "Materials Used in Aircraft Finishing". After the surface has been prepared, the procedure described above for varnishing wood should be followed. When the third coat of varnish has been applied it should be allowed to dry for at least 12 hours and then sanded smooth with #320 waterproof sandpaper. Additional coats of varnish may be applied with a spray gun or with a soft bristle brush, preferably a camel's hair brush. Each alternate coat should be water sanded smooth with a finer grade of waterproof sandpaper until the finish has been built up to the desired number of coats. Five to seven coats of varnish are usually considered sufficient for the purpose of providing a base for a high lustre finish.

The final coat of varnish should be allowed to dry at least 24 hours, after which time the lustre of the varnish may be brought out by hand rubbing a coat of wax over the varnish. In general, the paste waxes provide a more durable finish than do the liquid waxes, but care should be taken to see that they are applied only with a clean, soft cloth to prevent any possibility of scratching the sur-

RECOMMENDED AIRCRAFT FINISHES
(continued)

face. A rotary or figure 8 motion should be used in hand rubbing.

FABRIC COVERED PLYWOOD

Many plywood skins are covered with fabric to strengthen the plywood and to improve the appearance. Examples of this may be found on plywood covered wings and plywood monocoque fuselages. If the fabric is properly applied it increases the strength of the plywood up to 15%. A widely recommended procedure for applying fabric to plywood is given below.

Clean and sand the plywood, taking care to remove all excess glue, wax, etc. Prime the surface with one coat of clean "Lionoil" and allow it to air dry for 24 hours. Dry sand the surface smooth with fine sandpaper. Remove the sandpaper waste with a soft brush or air duster and apply two coats of clear nitrate dope, allowing 45 minutes between coats for drying. After the dope is thoroughly dry the fabric may be stretched and fastened into place. Extreme care should be taken to make sure that the cover fits snugly. If any small wrinkles remain after the cover has been fastened, these may be removed by moistening the fabric slightly with clean water. If the wrinkles are small they will disappear when the fabric dries.

After the fabric is in place, it may be doped to the surface with a stiff bristle dope brush. Note: Brush in one direction only in order to eliminate bubbles between the undercoat and the fabric. Punch the fabric with pins to release any imprisoned air, where necessary. The surface may now be finished in the same method used when applying dope to a fabric surface.

ALUMINUM AND ALUMINUM ALLOY SURFACES

Aluminum and dural surfaces to be finished must first be properly prepared to receive the finish. This is a very important item that must not be overlooked if a satisfactory finish is to be obtained. The preparation necessary for these surfaces will be found under "Preparing Surfaces for Finishing". One of the most suitable finishes for aluminum surfaces, from the standpoint of protection, is aluminum bronzing powder mixed with a suitable vehicle such as "Lionoil" or spar varnish. Two coats of this material are sufficient for the purpose of protection.

Aluminum and dural surfaces to be finished with lacquer should first be primed with a good oil base primer, and air dried for at least 12 to 24 hours. Five to seven coats of the desired color lacquer may be then sprayed on the surface, allowing from 30 to 45 minutes between coats for drying. These coats may be thinned from 10% to 35% to obtain the correct spraying consistency. Caution: As with dope, it is important that all blushes be removed immediately, or at least before another coat of lacquer is applied. This may be done in the case of a small blush, by moistening the area affected with a clean cloth which has been dampened with reducer. If a large area is affected, much better results may be obtained by spraying the entire surface with clear reducer.

RECOMMENDED AIRCRAFT FINISHES
(continued)

The final coat of lacquer should be thinned 50% with thinner and reducer as this thoroughly softens the preceding coats, allowing the final coat to flow smoothly into the body. After 24 hours the finish may be surfaced with rubbing compound and waxed.

The Aluminum Company of America recommends, "Where the entire metal structure of the airplane is formed from Alclad aluminum alloy sheet, no protection by chemical or organic means is normally necessary in order to preserve the structural integrity of the metal. Seaplane and float bottoms may be an exception to this rule, although we recommend its trial bare, for such a location. However, because of the weathering of the surface, some cleaning may be necessary in order to maintain a satisfactory appearance. This should be done periodically, depending on the conditions of the service. The exact method to be employed will also depend to a large extent upon the conditions of service. The cleaners used should be non-abrasive or but mildly abrasive in nature, and should not be of any composition which will chemically attack the aluminum."

STEEL TUBE STRUCTURES

Steel tube structures such as fuselages, control surfaces, etc., will rust quickly unless the proper protective finish is applied. This is especially true in seaplanes. Rust seriously impairs the strength of the structure and for this reason it is of utmost importance that the finish applied to steel tubing possess the highest rust preventing qualities possible. Where the facilities are available the following procedure is recommended for the external protection of steel tubing.

Sand blast the structure thoroughly, using not more than 150 lbs. air pressure. The sand blasting is done to clean the metal thoroughly, remove any scale and flux deposits from the welding, and to roughen the surface of the tube to provide the finish with a better tooth, or grip. After the structure has been thoroughly sand blasted it should be metallized immediately. Metallizing is a process of spraying molten metal directly on the structure. The metal used is usually cadmium. This results in a cadmium plated structure, which in itself is a good finish as a protection against rust.

The metallized fuselage is further protected by applying two coats of any good Bakelite varnish, allowing at least 12 hours between coats for drying. All parts of the structure that come in contact with the fabric should be given a coat of dope proof paint or should be otherwise suitably dope proofed.

If metallizing equipment is not available, the structure should be sand blasted if possible to provide a better base for the finish. If sand blasting equipment is not available the surfaces of the structure must be cleaned by hand, using steel wool and emery cloth. It is well to remember that any type of finish will adhere better over a slightly roughed surface than on a hard polished surface. After the structure has been thoroughly cleaned it should be washed

RECOMMENDED AIRCRAFT FINISHES
(continued)

with high test gasoline. The primer, or first coat, should be of "Lionoil", or a good oil base primer. The primer is covered with a second coat consisting of aluminum powder mixed with a suitable vehicle such as "Lionoil" or spar varnish. This finish should also be protected from the solvent action of dope by dope proofing all parts that will come in contact with the fabric.

ENGINES

The finish used on air cooled aircraft engine cylinders must be able to withstand the heat of the cylinder without cracking or peeling off. The finish must protect the cylinder against the effects of corrosion and from the abrasive effects of rain, sand, etc. There are several good proprietary products on the market which are designed especially for this purpose. They are usually some form of enamel and are used as described below.

Cylinders to be painted must be absolutely clean and free from grease of all kinds. It is a difficult and tedious job to properly clean air cooled cylinders by hand and much time and effort will be saved, and a better surface provided, if the cylinder can be cleaned with a sand blasting outfit. If this is done, care should be taken to protect all threads, machined surfaces, etc., or they may be damaged by the sand blast. One or two coats of the engine enamel are usually considered sufficient and, needless to say, a much better job will result if the finish can be applied with a spray gun. If the finish is to be air dried, at least 24 hours should be allowed for this purpose. The durability of almost any engine enamel is improved if it is dried by baking.

The crankcase may be finished in the same manner as the cylinder. Usually a contrasting color, such as slate blue or gray, is used for the crankcase. Engine accessories such as pushrod housings, rocker box covers, etc., are finished in the same manner although in some cases the material may be applied by dipping instead of brushing or spraying.

INSTRUMENT BOARDS

Many instrument boards are finished with a dull, crackled effect. This makes a very practical instrument board finish, as it is attractive and does not transmit a glare, as would a smooth, highly polished finish. There are several types of crackle and crystallizing lacquers for this purpose and as the method of application varies widely, the directions supplied by the manufacturers should be followed. However, in general the most durable finishes are the one-coat lacquers that are applied directly to the metal or over an oil base primer, and dried by oven baking.

PREPARING SURFACES FOR FINISHING

The success of any finishing job depends to a large extent on the careful and thorough preparation of the surface to be finished. The most common fault of the inexperienced mechanic is to attempt to apply finishes over surfaces that are not absolutely clean. Thorough cleaning of the surface is necessary to insure the finish adhering properly and to remove any foreign substance that may be detrimental to the finishing material. Almost every finishing job presents its own particular problems, but by keeping in mind that the surface must be clean, a little judgment and experience on the part of the mechanic will bring about the desired results.

General information about preparing the surfaces of various kinds of airplane materials for finishing, is given below.

PREPARATION OF WOOD

All wood structures should be sanded or scraped to remove all traces of dirt, grease, oil, wax, etc. All hardened glue or seam compound of any nature should be removed before the primer is applied. If the wood is to be finished for protection only, such as wing spars, ribs, interiors of wood structures, hulls, etc., the above preparation will be sufficient.

Wood to be finished with a high lustre, such as cabin trim, control wheels, paneling, etc., must, in addition to being clean, be absolutely smooth. It is well to remember that any scraper marks or sandpaper scratches will show up even more plainly after the finish is applied. A fine grade of steel wool may be used to advantage after the material has been scraped and sanded. On exceptionally hard woods and especially those with a curly grain, an even smoother surface may be acquired by moistening the wood slightly with water, to raise the grain. Using fine sandpaper, sand the raised grains, or fibers. After the wood has dried it is ready for the priming coat.

If a paste filler is to be used it should be applied immediately after the surface has been cleaned. After the filler has had sufficient time to dry the surface should again be sanded to remove any unevenness caused by the filler. It is understood that waste from the sandpaper should be removed before any of the finishes are applied. Where available, this is best done with an air duster (see "Spray Equipment"). A dusting brush is recommended as a substitute for an air duster.

PREPARATION OF WOOD SURFACES FOR REFINISHING

It is very often either necessary or desirable to refinish wood surfaces by removing the old finish entirely and refinishing the bare wood. In this case it is not usually necessary to scrape the surface, unless the original surface has been damaged. If paint or varnish remover has been used to remove the original finish, sufficient time should be allowed for the wood to dry thoroughly before it is sanded smooth. If lacquer or dope is to be applied, great care must be taken to make sure that the surface is free from any wax deposits which may have been left by the paint remover. This

PREPARING SURFACES FOR FINISHING
(continued)

may be done by washing the surface with high test gasoline, followed by a washing with thinner. This precaution will be unnecessary if a remover is used which is free from wax. Surfaces of any kind that have been prepared for finishing should never be touched with the bare hands before the primer is applied, as there is usually a certain amount of oil in the skin which may leave a slight deposit of oil on the surface sufficient to cause the finish to lift.

PREPARATION OF STEEL

Steel surfaces to be finished should be free from any wax, grease, or oil. This may be done by washing the surface with high test gasoline. This should be followed by again washing the surface with thinner or reducer to remove any traces of the gasoline. If there are any rusty spots on the metal they should be entirely removed with emery cloth or steel wool before finishing. Loose scale around welds should be chipped off and the surface smoothed with emery or steel wool.

Finishes will not adhere as well over highly polished metal surfaces as they will over surfaces that have been slightly roughed. For this reason a sand blasted finish provides about the best surface for the finish.

PREPARATION OF ALUMINUM AND ALUMINUM ALLOYS

All corrosion spots must be very carefully removed from aluminum and aluminum alloy surfaces before the finish is applied. This is necessary both from the standpoint of providing a better base for the finish and protecting the metal. This may be done by scraping the corrosion away with a scraper or steel wool. The area should then be neutralized to prevent further corrosion. Note: Vinegar should not be used for this purpose because it contains a solid dissolved matter which is deposited, thereby defeating its own purpose.

Before applying the priming coat the entire surface should be cleaned off or neutralized by washing with a phosphoric acid solution such as, for example, "Deoxidine". If the surface has been corroded even slightly it is sometimes desirable to follow this cleaning by washing with a 5% solution of warm potassium dichromate. Caution: Rubber gloves should be used to protect the hands. After the surface has been washed with solvent cleaner it should be washed off with water, preferably warm water. Note: High test gasoline or lacquer thinners should never be used as a solvent cleaner on aluminum or aluminum alloy surfaces, as they merely dilute the oily surface and will not neutralize the alkali on the metal. The use of these cleaners will result in poor adhesion of the primer and will not check incipient corrosion.

Anodizing (described under Protection of Metals) is the most satisfactory method for preparing aluminum and aluminum alloy surfaces for finishing. It is recommended by the Aluminum Company of America.

THE APPLICATION OF FINISHES

There are several methods of applying paints, varnishes and lacquers to parts and structures. Finishes may be applied by brushing, spraying, dipping, rolling and tumbling. Rolling and tumbling have not been used to any great extent in aircraft finishing as yet and for this reason will not be discussed here.

BRUSHING

Finishes have long been applied to all types of surfaces with a brush. This is a satisfactory method and with skill an attractive finish may be secured. Where small surfaces are to be finished, especially where the finish is of various types, such as cabin trim, instrument boards, wheels, etc., brushing is the most satisfactory method of application.

All material to be applied by brushing should be thinned or reduced to the proper consistency. Materials that are too heavy will have a tendency to rope or pull under the brush. This results in an uneven surface or a streaked job. Materials that are too thin are likely to cause runs, or will not cover the surface adequately. The correct consistency of the various materials can best be determined by trial. However in general the consistency should be about the same as that of cylinder oil. This, of course, will vary with the type of material used, therefore the manufacturer's recommendations in regard to consistency and reducers should be closely followed.

If a good finish is to be obtained, brushes of inferior quality should not be used. Only good grade brushes, preferably those with long, soft bristles that will not fall out, should be used. A good brush is essential to a good job and will last for a long period of time if it is promptly and properly cleaned and stored after use. Brushes should always be cleaned in the solvent of the material that was used. If the solvent fails to clean the brush sufficiently, it should be cleaned with thinner or reducer, and stored so that the bristles remain straight. Note: Never stand a brush on the bristles to dry, as this permanently curves the bristles, making further use of the brush extremely difficult.

The widths of brushes used in aircraft finishing range from 6" down to the extremely fine brushes used in lettering. The wider brushes, from 3" to 6" are used in applying finishes to large, unbroken surfaces such as in doping a wing. Enamels and varnishes are rarely applied, even on large surfaces, with a brush which is wider than 3". A 2-1/2" or 3" brush is recommended in general for applying finishes of this type to large surfaces. Naturally, the smaller surfaces require narrower brushes. There is no definite rule for the size of brush to be used, but a faster, smoother job will result if the widest brush possible, up to 3" is used.

Material should be applied with a well filled brush to assure a surface free from streaks. The brush should be dipped in the material about 1/2 to 3/4 of its bristle length and the excess material drained from the brush by pressing it against the inside surfaces of the container. The excess material should not be removed

THE APPLICATION OF FINISHES
(continued)

from the brush by scraping it over the edge of the container as this results in a waste of material due to its running down the outside of the container. The brush should be held in a comfortable position in such a manner that the stroke may be made with a free arm movement. Many painters prefer to hold the brush so that the fingers are near the bristles.

COMMON FAULTS OF BRUSH PAINTING

Some of the most common faults in applying finishes by brush are runs, laps and poorly covered areas, usually referred to as "holidays". Runs are usually caused by the use of materials of too light a consistency, or when attempting to work with a brush that is too full. The remedies for each of these situations is apparent. Laps, or overlaps as they are sometimes called, are sections of the surface that show a definite contrast to the proper finish. This may be caused either by an excess of material, or the difference in time of its drying. To avoid laps requires skill on the part of the painter. Holidays, or poorly covered areas, are usually due to an inexperienced or careless workman. This is especially apparent in finishing such surfaces as wing structures, steel tube fuselages, etc., where it is difficult for the painter to remember the portions he has finished. There is only one remedy for this and that is to apply the material in a systematic, thorough manner.

SPRAYING

Many types of materials may be applied with a spray gun, including varnish, enamels, and synthetic base paints as well as dopes and lacquers. The most important things to remember in spraying any kind of material are, first, that the spray equipment must be clean, and second, that the materials being sprayed must be clean, free from any lumps or skin, and thinned or reduced to the proper consistency for spraying.

The correct procedure for applying the various kinds of materials with a spray gun will be determined largely by experience, but in general, the directions given under the paragraph on spraying dope, on the pages devoted to "The Application of Dope", apply to all spray painting.

DIPPING

The application of finishes by the dipping method is usually confined to factories or large repair stations. As its name implies it consists of dipping the entire structure to be finished into a suitable vat filled with the finishing material. Usually only the first, or priming coat, is applied in this manner. If the surface is to be finished for protection only, the entire job may be done by dipping. Dipping is very often done in connection with oven drying.

LETTERING AND DESIGN PAINTING

All airplanes must carry either the C.A.A. registration numbers or license numbers. In addition to the numbers carried, almost all airplanes have some design painting, such as an insignia or an emblem of some type. In recovering or refinishing airplanes, this work is usually done by the mechanic.

PLACES AND DIMENSIONS OF MARKS

"Identification marks shall be located as follows:

(A) On Airplanes and Gliders.- On the lower surface of the lower left wing and the upper surface of the upper right wing, the top of the letters or figures to be toward the leading edge, the height to be at least four-fifths of the mean chord: Provided, however, that in the event four-fifths of the mean chord is more than 30 inches the height of the letters and figures need not be more, but shall not be less than 30 inches. If the lower left plane is less than one-half the span of the upper left plane the letters or figures thus described shall be on the under surface of the upper left plane, as far to the left as is possible. In the case of a monoplane the mark shall be displayed on the lower surface of the left wing and the upper surface of the right wing in the manner thus described. On gliders the letters and/or figures shall be displayed in the same manner and place prescribed for airplanes except the minimum size shall be 15 inches in height and 10 inches in width, using a 2-1/2 inch stroke. The marks shall also appear on both sides of the vertical tail surface or surfaces, of size as large as the surface will permit, leaving a margin of at least 2 inches.

"(D) The width of the letters and figures of all marks shall be at least two-thirds of the height and the width of the stroke shall be at least one-sixth of the height. The letters and figures shall be painted in plain black type on a white background, or in any color on any background, but there must be a strong contrast between the two. The letters and numbers must be uniform in shape and size." - from Air Commerce Regulations.

LETTERING LAYOUT

Probably the easiest way to lay out block letters on a wing is to use a chalk line to mark the location for the top and bottom of the numbers. A yard stick may be used for the vertical lines. In most cases the vertical lines can be laid out parallel to the ribs. The letters are usually blocked in with pencil.

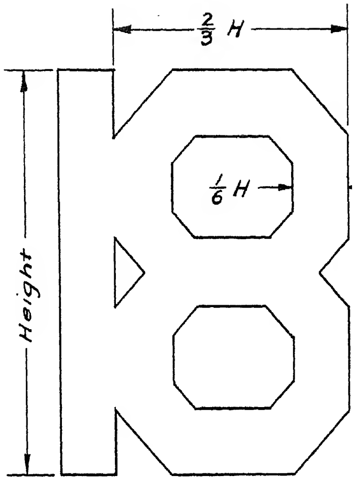
For outlining the smaller block numbers and letters, such as those required on the tail group, much time will be saved if a lettering guide of the correct size and proportion is made. A lettering guide of this nature is shown in Fig. I. Using this guide as a template, the outlines of any number and most letters can be quickly traced directly on the surface.

MASKING

After the numbers or letters have been outlined by pencil, they should be blocked in with masking tape, as shown in Fig. II. If the

LETTERING AND DESIGN PAINTING (continued)

letters are to be painted by brush a single line of masking tape, as shown, will be sufficient. If the letters are to be spray painted, any portion of the wing likely to be affected by the spray should also be masked. This may be done by covering the surfaces with paper held in place with masking tape.



Lettering guide - FIG. I

After the masking tape has been applied the edges of the tape next to the number must be thoroughly smoothed down with some smooth, hard object to prevent the wet paint spreading under the masking tape, leaving an uneven outline.

STRIPING

Wide stripings, such as the arrows on fuselage covers, etc., are very often applied by masking all of the surface except the stripe. The stripe may then be sprayed with three or four coats of the desired color. Care should be taken to see that the inside edges of the tape are pressed down tightly to the surface.

Narrow stripes, such as those used on cowling louvres, are best applied with a standard striping brush. The standard striping brush is a short handled brush with exceptionally long bristles, usually about 2" or 3" long. The stripe is made by holding the brush at an angle of about 15° to the surface, and moving it forward with a rapid, free arm movement. The long bristles have the advantage of not transmitting the unsteadiness of the hand to the stripe. A little experience with this type of brush will enable the mechanic to produce a steady, clearly defined stripe.

STENCILS

Where a number of designs of the same type are to be applied to a surface, and where appearance is not of prime importance, it is desirable to use a stencil, as this is a much faster method of lettering or design painting. Places where stencils may be used to advantage include the "No Step" signs, "Lift Here" signs on wings, "Capacity of Baggage Compartment" signs, etc.

The stencil consists of a plate, usually of stiff cardboard or thin metal, from which the design has been cut. The design is

LETTERING AND DESIGN PAINTING (continued)

transferred to the surface by holding or fastening the stencil to the surface with masking tape and spraying over the entire stencil. If the stencil is sprayed the paint should be used full-bodied, otherwise it will run underneath the stencil, thereby spoiling the design outline. Stencils may also be applied by using a short, heavy bristled stippling brush. If this is done the material should be used full-bodied and should be applied with vertical strokes. Do not attempt to transfer the design by brushing over the surface of the stencil, as runs will surely result.

Fig. II

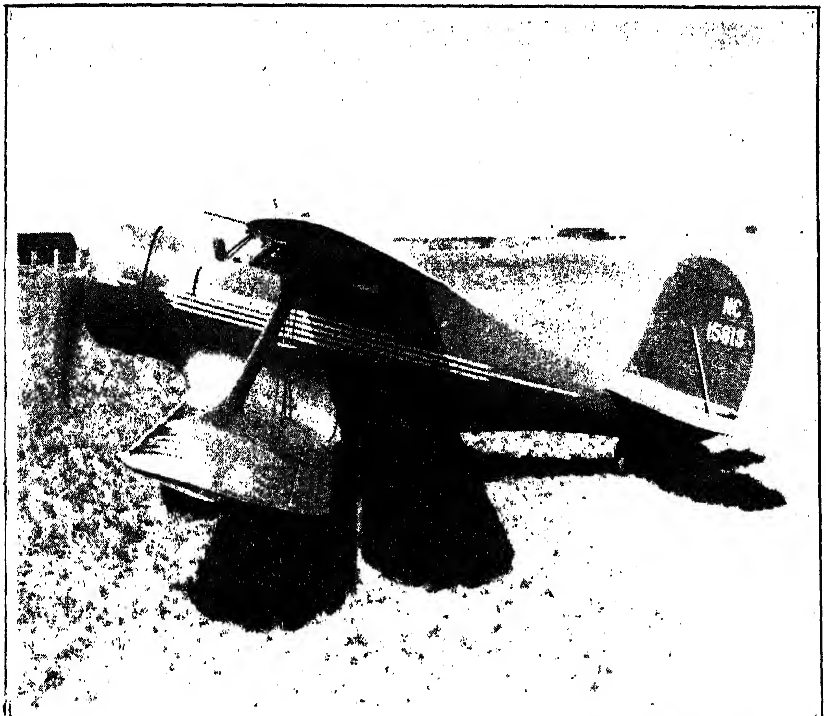
TRANSFERS (DECALCOMANIA)

Many designs are transferred to airplane surfaces with manufactured transfers, such as manufacturers' emblems, etc. There are various types of transfers, and the directions for their application supplied by the manufacturer should be followed carefully. Generally speaking, they are transferred by moistening the surface with water and smoothing the transfer into place. Great care should be taken at this point to make sure that the transfer is placed squarely and that no wrinkles are present. After the transfer has been smoothed into place it may be removed and the design will be left on the surface. The design should then be protected with clear varnish or clear lacquer.

FREE HAND DESIGN

The free hand painting of designs on airplanes requires considerable experience in that line; however, if the design must be painted by the mechanic the following suggestions may be of assistance: Draw a pencil outline of the desired design on a large sheet of paper. This allows for erasures and corrections until the design is suitable. After the design is complete, place the paper in a sewing machine and stitch, without thread, along each line of the design. This causes a series of small holes along the design outline. Fasten the perforated design in the correct position with masking tape. The design outline may now be transferred to the surface by rubbing chalk over the perforations.

RIGGING
HANDLING
MAINTENANCE



Courtesy Beechcraft Corp

BEECHCRAFT WITH 225 H.P. JACOBS

THE AIRPLANE AND ITS PARTS

While the average individual interested in aviation probably has a good general idea of the various types of airplanes, it seems advisable to classify them definitely for future reference.

The general term "airplane" covers all types of heavier-than-air craft, whether landplanes, seaplanes, flying boats or amphibians. The first subdivision is made according to the arrangement of the engine or engines. If the engine is mounted so that the propeller is in front of it, and hence usually in front of the wings, "pulling" the ship, the plane is called a tractor. If the engine is mounted so that the propeller is behind it, the plane is called a pusher. This arrangement is not usual except in flying boats though some landplanes, such as the Curtiss Junior, are pushers. Occasionally, as in the twin-hull Italian Savoia-Marchetti, one engine is mounted as a tractor and a second immediately behind it, or in tandem, as a pusher. The second subdivision depends upon the number and arrangement of the lifting surfaces. Only two are in general use: the MONOPLANE, with one wing, or at least with the wings in only one plane, and the BIPLANE, which has two sets of wings, one above the other. The triplane, with three sets, and the multiplane, with more than three, have been discarded.

MONOPLANES are divided into four general types, the parasol, high wing, the midwing, and the low wing.

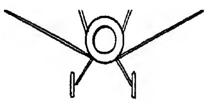


FIG. I

The parasol type carries the fuselage supported under the wing by struts, as in Fig. I. Examples are the Fairchild 22 and the Lockheed Air Express. In small ships, this design provides excellent visibility and lessens the likelihood of damage to wings on the ground.

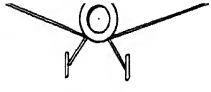


FIG. II

The high wing monoplane is quite similar to the parasol except that the wing is attached directly to the top of the fuselage, as in Fig. II. There are many examples of this type, some of them being the Aeronca C-3, the Taylor Cub, the Monocoupe, and the Luscombe Phantom.

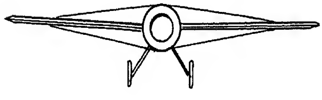


FIG. III

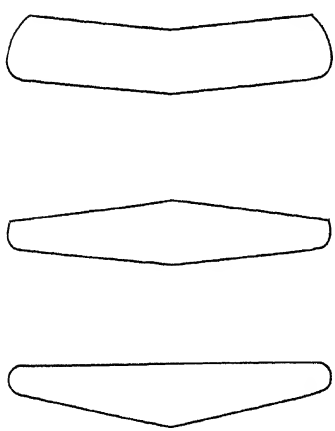
The midwing design is seldom used because the wing bracing must be carried through the fuselage, as can be seen in Fig. III. Furthermore, it is difficult to provide proper vision. One example is the Heath CNA-40.

THE AIRPLANE AND ITS PARTS
(continued)

The low wing type has become quite common, particularly in the large transport ships and others with retractable landing gears, as the wings afford an excellent place to put the wheels when they are retracted. Examples are the Douglas DST, the Boeing 247-D, the Aeronca LA, the Curtiss-Wright Coupe and many others.

BIPLANES do not have the sharp differences found in monoplanes. There is one type, which is half-way between a biplane and a monoplane, called the sesquiplane. In this, the lower wing is only about half as large as the upper. The Nieuport, used during the world war, is a famous example, but practically no modern ships employ the design any more. Biplanes are usually made with the upper wing ahead of the lower, which is known as <u>positive</u> stagger, though, as in the Beechcraft, the lower wing may be ahead, which is <u>negative</u> stagger. In rare cases, the upper wing is directly over the lower when the ship is in flying position, in which case it is called an orthogonal biplane.

THE PLAN FORM of wings may vary with the purposes of the ship. There are three general forms of wings, as shown in Fig. V. The leading edge is toward the bottom of the page. "A" is the straight wing, "B" the swept back, and "C" the tapered. Or a wing may be both tapered and swept back, as in "D".
The question as to whether a tapered wing is considered as having sweep-back or not, depends upon the line made by the center of pressure of each wing, shown dotted in each view. If this line, usually taken at a point about one-third of the chord-length from the leading edge, is straight, the wing is not swept back. Tapered wings are more expensive as no two ribs on the same side are alike and production methods are not as effective as when all ribs are the same.



D

Occasionally, the "gull wing" shown in Fig. VI. is used. A plan form and elevation of the type shown in "A" is usually referred to in this manner, but the

THE AIRPLANE AND ITS PARTS
(continued)

true gull wing appears in elevation as shown in "B". The derivation of the name is obvious. This type is ordinarily the most expensive of all.

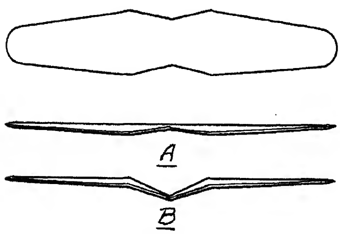


FIG. VI

To secure lateral stability, the wing of a monoplane and one or both wings of a biplane, are raised at the outer ends as in Fig. VII. This is referred to as "Dihedral" and the "dihedral angle" is ordinarily considered the angle between the wing and a horizontal line, indicated as "A" in the top figure. Strictly speaking, the dihedral is the angle between the wings or "B", but trade practice uses "A" as it is simpler to measure in rigging.

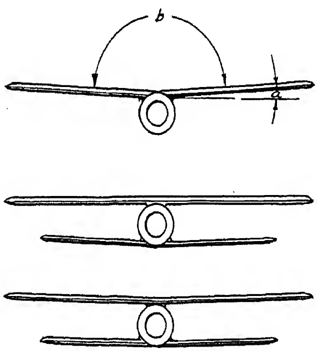


FIG. VII

Airplanes are also classified as landplanes, seaplanes, flying boats and amphibians. Reference to the section "FLOATS AND HULLS" will clarify the distinctions between seaplanes and boats. Amphibians are ships equipped to land on and take off from either land or water, and, as a rule, are flying boats equipped with retractable wheels. However, some, as the Seversky, illustrated in the section "HANDLING AND MAINTENANCE OF SEAPLANES", have wheels mounted in floats. This last type has much greater possibilities than have yet been developed.

THE MAIN DIVISIONS of the airplane are the wings; the fuselage or body; the power plant, which includes the engine, propeller, gas and oil tanks and all accessories; the empennage or tail group, which includes the vertical fin, the rudder, the horizontal stabilizer and elevators; and the landing gear or floats.

The various groups are discussed in greater detail in the sections devoted particularly to their rigging and maintenance.

It is recommended that the reader secure a copy of the N.A.C.A. report No. 474 "Nomenclature for Aeronautics" and familiarize himself with aeronautical terminology. This may be obtained by sending a dime to the Supt. of Documents, Washington, D. C.

THE AIRFOIL

For the purposes of the following discussion, an airfoil is a surface or portion of an airplane which, when moved through the air, produces lift.

The airfoil section is the section that would be shown if an airfoil were cut through in the direction of its motion through the air. Airfoil sections are of many shapes and their characteristics depend upon these shapes. The characteristics cannot be calculated but are found by testing the airfoil in a wind tunnel, which is simply a large tube through which a current of air is passed at high velocity. For the characteristics are the same whether the airfoil is passed through the air or the air passed by the airfoil. A model of the airfoil is placed in the wind tunnel and the forces on it measured by suitable instruments.

The effect of the air blowing on the airfoil may be resolved into two forces, one vertical and one horizontal. (Vertical and horizontal refer to the directions when the airfoil is on the airplane. In the wind tunnel it may be set in whatever position is most convenient for measuring the forces.) The vertical force is called lift and the horizontal force is called drag.

At this point it may be well to illustrate the terms which are standard nomenclature.

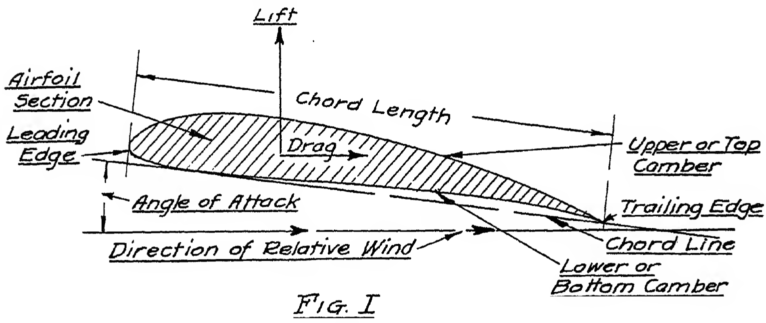


FIG. I

The forces on the airfoil or on any other part of the ship, which are due to the wind, vary as the square of the speed. In other words, if the wind exerts a given amount of force at three miles per hr., at six miles per hr. it would exert not twice as much but four times as much force. To make it still clearer, 3 x 3 = 9; 6 x 6 = 36; 36/9 = 4.

This fact being established, if the force at one speed is known, it is possible to determine its amount at any other speed. For convenience, the forces on the wind tunnel model are worked out in units of one square foot at a speed of one mile per hr. The unit of the vertical force, on this basis, is called the Lift Coefficient, which is abbreviated in several ways, the most common of which are K_y , K_l , and L_c . Hence, the symbol K_y means the fraction of a pound that one square foot of a given airfoil will lift at one mile per hour. Knowing this it is a simple mat-

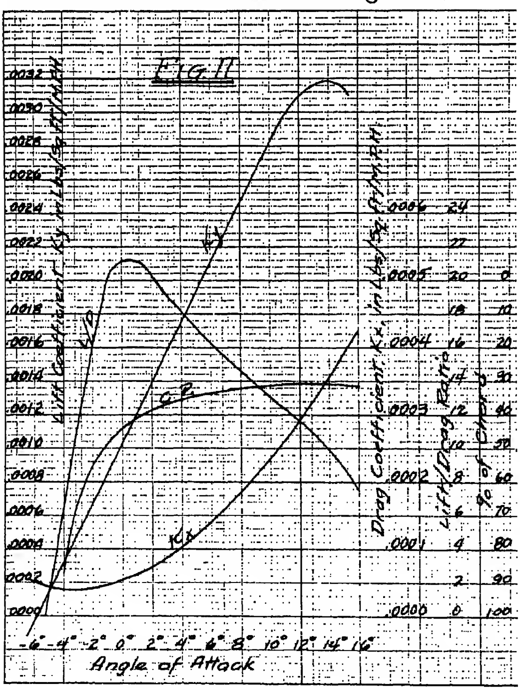
THE AIRFOIL
(continued)

ter to find how much a wing will lift at any speed. For example, if K_y is .003, how much would a wing with 200 square feet of area lift at 50 m.p.h. (miles per hour)? $.003 \times 200 \times 50^2 = .003 \times 200 \times 2500 = 1500$ lbs.

The horizontal force, when worked down to the same units, is called the Drag Coefficient, abbreviated to K_x, K_d, or D_c. It is used in the same manner. When these principles are put into formulae, we have:

$$\text{Lift} = K_y\ A\ V^2$$
$$\text{Drag} = K_x\ A\ V^2$$

Both the lift and the drag are affected by another factor, and that is the angle between the chord line of the airfoil and the wind. This angle is called the angle of attack. The lift increases in approximately direct proportion to the increase of the angle of attack. If the chord line is above the line of wind, as shown in Fig. I, the angle of attack is considered as positive; if the chord line is below the line of the wind, the angle is considered as negative. Most airfoils have upward or positive lift even at small, negative angles of from - 2° to - 4°, but, of course, there is a point where there is no lift in either direction. The angle at this point is called the Angle of Zero Lift. Below this point the lift becomes downward or negative.



Somewhere in the lower range, usually about the point where the chord line is exactly in line with the wind (or at an angle of attack of zero degrees - 0°) the drag is lower than at any other angle. This is called the Angle of Minimum Drag.

While, as stated before, the lift increases with an increase of the angle of attack, this, unfortunately, does not continue indefinitely. Somewhere between 15° and 25°, depending on the airfoil section, the lift increases no more but, on the contrary, begins to decrease if the angle is increased further. This point is desig-

THE AIRFOIL
(continued)

nated by three different expressions, the Angle of Maximum Lift, the Critical Angle, or the Burble Point. This is the point where the wing "stalls". The drag, however, keeps right on increasing.

In working out the lift and drag coefficients, the angle of attack must, of course, be taken into consideration. The coefficients are determined at a number of different angles, usually 2° apart and then plotted on a chart, as shown in Fig. II. These curves are called curves of Airfoil Characteristics.

Charts like this are made for every airfoil when it is tested, and by referring to them the various characteristics can be immediately determined and compared. The line marked L/D is simply the lift coefficient divided by the drag coefficient, and shows the efficiency of the wing at any given angle.

As the wing changes its angle with respect to the wind blowing against it, the forces set up by the wind shift their positions. The center of these forces is called the Center of Pressure, abbreviated to the C.P. The line on the chart labelled "C.P. in % of chord" shows the position of the C.P. measured in percentage of the chord length from the leading edge. It will be noted that the C.P. moves forward as the angle increases and vice versa.

The question may arise as to what causes lift, especially at low angles. It is simple to understand at high angles, as nearly everyone has flown a kite and the principle is similar. However, since the airfoil has an appreciable thickness and, furthermore, is curved on both top and bottom surfaces, (for even though a considerable portion of the bottom may be flat, it is curved at the nose) the action of the air is not the same as in the case of the kite. As the air strikes the leading edge or nose of the airfoil, some of it is deflected downward under the airfoil, increasing the pressure. The remainder is deflected upward. The combination of the two produces high pressure on the bottom and low pressure over the top surface. About two-thirds of the lift is due to this low pressure on the top surface. The ideal of the designer is, of course, to secure the maximum effect from this variation of pressure with a minimum of the disturbance and turbulence which causes drag.

The important points to remember are that lift may be increased by changing the airfoil section (as in the use of flaps), by increasing the angle of attack (dropping the tail), by increasing the speed (opening the throttle) or by increasing the wing area. The last cannot be done in any ordinary airplane while in flight.

BALANCE

ty - It is important that the aviation mechanic understand the following discussion. In simple language, the center of gravity (usually written c.g.) of an object is the point around which it balances. The horizontal c.g. is the balancing point along a horizontal axis and may be represented by a vertical line passing through this point. Thus, in Fig. I the c.g. along the horizontal axis x - x (or any other horizontal line) is represented by the vertical line Z - Z. If a hole were bored through the object anywhere on the line Z - Z, and the object supported on a pin run through the hole, it would remain in the horizontal position shown unless disturbed by an outside force.

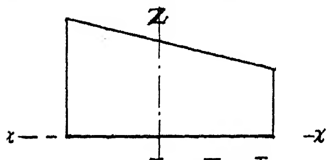


FIG. I

The vertical c.g. is the balancing point along a vertical axis and may be represented by a horizontal line passing through that point. In Fig. II, the c.g. along the vertical axis z - z (or any other vertical line) is represented by the line X - X. In other words, if the object were stood up on its end, it would be in balance if supported anywhere along the line X - X.

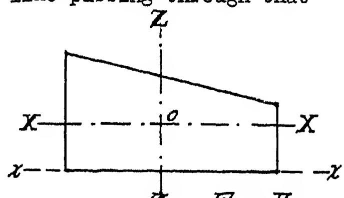


FIG. II

Now, since the object balances horizontally anywhere along the vertical axis Z - Z, and balances vertically anywhere along the axis X - X, obviously, if it is supported on a pin passed through the intersection of these axes at O, it will balance in both directions. In other words, when supported in this manner, it may be rotated into any position, as, for example, that shown in Fig. III, and will remain in that position until acted upon again by outside force.

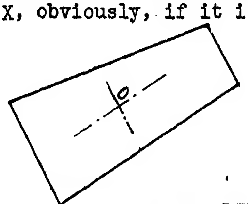


FIG. III

One other axis must be considered, namely, the transverse or Y axis shown in Fig. IV. Since airplanes are usually symmetrical about the centerline, there is seldom any occasion to be concerned about the transverse c.g. In Fig. IV the object has been turned 90° so that the small end is shown. The X axis is, of course, simply a point in this view and is at the intersection. The c.g. along any horizontal axis, as y - y, will be on the line Z - Z, as before, and the c.g. along the vertical axis Z - Z will be on the line Y - Y.

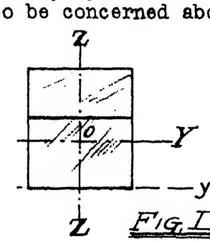


FIG. IV

The intersection of Y - Y and Z - Z locate the c.g. in all directions. Thus the c.g. about any axis, passing through the object in any direction is at common the intersection of all three axes as shown by

BALANCE
(continued)

the point O in Fig. V.

Moments and Moment Arms - It is often desirable to find the c.g. of a group of objects. This is done by means of moments, which in this case has nothing to do with time. A moment, in engineering language, is simply force or weight multiplied by distance. The distance is called the arm. It may be thought of as leverage. If we set a beam on a single point of support, as shown in Fig. VI, and then place a weight of 4 lbs. on the beam at a distance

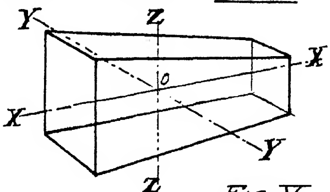


FIG. V

of three feet or 36 inches from the support, the moment, about the point of support, O, is 12 foot-pounds (ft.lbs.) or 144 inch-pounds (in.-lbs.), neglecting the weight of the beam itself. The moment arm is, of course, 3 ft.

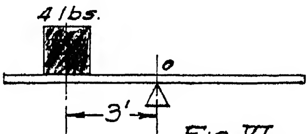


FIG. VI

Obviously, the beam will now rotate to the left, or counter-clockwise. To prevent this, we must produce an equal moment in the opposite direction. This may be done by placing a weight on the other side of the support. If the weight is lighter, it must be further away from the support than the first weight; if it is heavier, it must be nearer. If a 3 lb. weight were used to offset the moment of 12 ft.-lbs. then it would have to be 12/3 = 4 ft. from the support, as shown in Fig. VII. The point O is then the c.g. of the two weights. Since the weight of the beam is neglected, it may be left

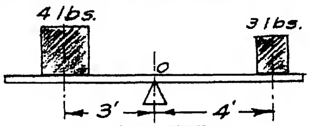


FIG. VII

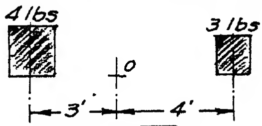


FIG. VIII

out of the picture entirely. The figure will then appear as in Fig. VIII. If an additional weight of six pounds were put on the left side of O, at a distance from it, for example, of 4 ft., then its moment would be 24 ft.-lbs., and a counter-moment of that amount would have to be set up. This could be done by putting a 24 lb. weight on the opposite side at a distance of one foot away from O; a 12 lb. weight 2 ft. away; a 6 lb. weight 4 ft. away, or by any other combination, the product of which is 24. Or, since the total moment on the left side is 24 + 12 = 36 ft.-lbs., the 3 lb. weight on the right side could be replaced by one of 9 lbs., which multiplied by 4 ft. gives 36 ft.-lbs. Thus, any number of weights may be used on either side, and provided the sum of the moments on one side is equal to the sum of the moments on the other side, the weights will still balance.

So far, the discussion has concerned itself with moments about

BALANCE
(continued)

a balancing point. The next step is to find the c.g. of a group of weights. This may be done easily by the use of moments about a reference point outside of the group. Assume the arrangement of weights shown in Fig. IX. The weight of the beam is neglected. The distances from the reference line a - a, or the arms, are given in the figure. Tabulating the moments, we have

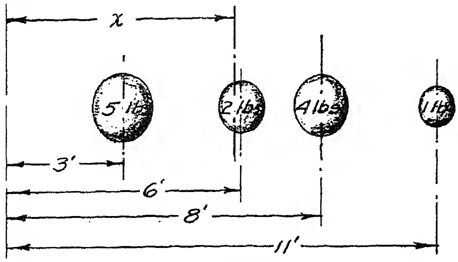


FIG. IX

5 lbs.	x 3 ft.	= 15	ft.lbs.
2 "	x 6 "	= 12	"
4 "	x 8 "	= 32	"
1 "	x 11 "	= 11	"
		70	

Then the distance, x, to the balancing point or horizontal c.g. of the group is 70 ft.-lbs./12 lbs. = 5-10/12 feet, or 5 ft. 10 inches.

Balancing the Airplane - Before an airplane is built an accurate detailed weight estimate of all the parts and the loads to be carried is made. The position of the center of gravity of each of these weights is also determined. From the two sets of figures it can be determined just where the center of gravity of the airplane will be and whether it is in the right location with respect to the wings. If not, the design is modified until the desired relation is secured. As the drawings for each part are made, the weight of the part is accurately calculated and compared with the original estimate. If there is much variation, the part is redesigned or some other part is modified to compensate for the change.

The weight of the plane with all the load it is intended to carry is called the gross weight. This is divided into the weight empty and the useful load. The weight empty, as the term implies, is the weight of the ship with all its necessary parts but without gas, oil, crew, passengers or baggage. These make up the useful load. The pay load is that portion of the useful load which produces revenue, in other words, the passengers or express and baggage only. Some ships have been produced in which the useful load was equal to the weight empty, but not many are so efficient.

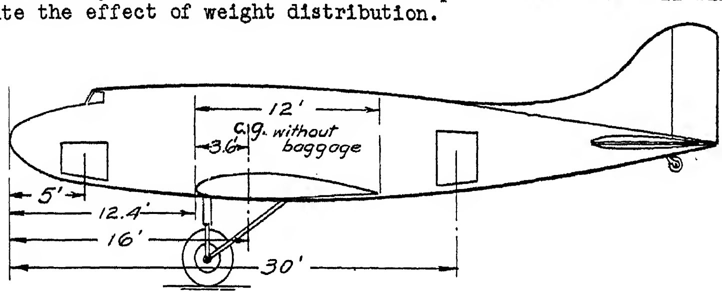
It is not a function of the mechanic to make balance calculations. However, he should understand how it is done. The procedure is identical with that illustrated in Fig. IX. A reference line, usually at the front of the propeller nut or spinner, is established. The distance from this line to the c.g. of each item is then measured on an accurate scale drawing of the airplane. Usually from 20 to 40 items are considered and a table, similar to that below, made for various conditions of loading such as with pilot alone and no fuel, pilot and full tanks, pilot and half the pay load, full load, etc. Both horizontal and vertical locations of the c.g. are calculated. A convenient reference line for calculating the vertical c.g. is a horizontal line through the center of the axle. The vertical distances from this line to the c.g. of each item are used

BALANCE
(continued)

as arms and the calculations carried out exactly the same as in the case of the horizontal c.g. Arms or distances are usually measured in inches though sometimes feet and decimal parts of a foot are used. The horizontal c.g. should be between 25% and 30% of the wing chord, measuring from the leading edge of the wing.

Note that the greater the distance from the reference line to the item, the greater the effect on the location of the c.g. of the ship. Thus, a small weight near the tail may affect the balance much more than a greater weight located in the cockpit. Mud and dirt in the tailskid opening may cause pronounced tail-heaviness, especially in a small airplane. The same is true of excess baggage carried in compartments toward the rear of the ship. Tail-heaviness is a dangerous condition as it tends to produce a stall followed by a flat spin from which the recovery may be difficult.

A study of the balance of the transport shown below will illustrate the effect of weight distribution.



Distances are given in feet to simplify the calculations. The ship is loaded, ready for flight, except for the baggage. The weight without baggage is 15,000 lbs., and the c.g. located as shown Since the c.g. is 3.6 ft. from the leading edge and the chord is 12 ft., the ship is balanced at 30% of the chord. 1400 lbs. of baggage, mail and express are to be carried. If this is all put in the rear compartment, the location of the c.g. is as shown in the table below Using the nose of the fuselage as a reference point:

15000	x	16	=	240,000
1400	x	30	=	42,000
16400				282,000

The distance from the nose to the c.g. is 282,000/16,400 = 17.2. Hence, the distance from the leading edge of the wing to the c.g. is 17.2' - 12.4' = 4.8' or 40% of the chord, which is much too tail-heavy. By putting 800 lbs. in the front compartment and 600 in the rear, we have the following:

15,000	x	16	=	240,000
800	x	5	=	4,000
600	x	30	=	18,000
16,400				262,000

The distance from the nose to the c.g. is 262,000/16,400 = 15.98 ft, which is satisfactory.

While the mechanic is seldom required to calculate the bal-

BALANCE
(continued)

ance in the manner just shown, he may be called upon to locate the actual c.g. of a complete airplane. This is quite simple if the necessary scales are available. Three sets of scales are needed, two of which should have a capacity of at least half the weight of the airplane. The third should be able to carry the weight on the tail skid.

Roll the wheels onto the heavy scales, one wheel on each and block the wheels so they won't roll off. Put a box or some other blocking on the third scale high enough to raise the tail into the flying position. If extreme accuracy is desired, the fuselage may be levelled as described under "RIGGING". A diagram is shown in Fig. I.

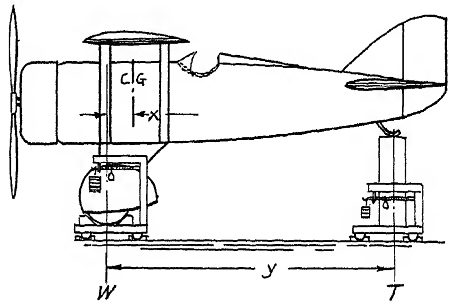
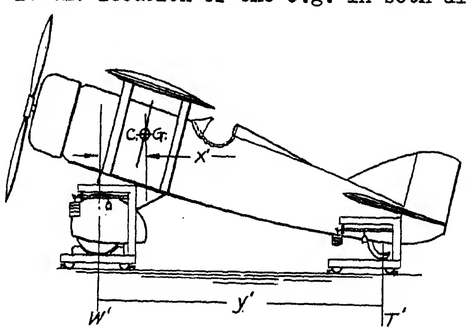


FIG. I

Drop a plumb line from the point where the skid touches the box and measure accurately the distance, in inches, from the line to the center of the axle. This distance is y, on the diagram. Add the readings on the scales under the wheels, deducting the weight of the chock. The sum of these readings is W. Obtain the weight on the rear scale, minus the blocking. This is T. Then $X = \frac{T \times Y}{W + T}$

If it is desired to obtain the vertical position also, a scale drawing of the ship is necessary. Draw a vertical line through the point already located.

Repeat the weighing procedure but with no blocking under the skid. Draw another line through the point thus obtained. Where the lines cross is the location of the c.g. in both directions. See Fig. II.



THE THREE AXES

In order to understand properly the movements of an airplane in the air, one must have a thorough conception of the three axes around which it may move. Fig. I illustrates these axes, which may be thought of as long rods, each passing through the center of gravity of the airplane and each at 90° or perpendicular to the other two.

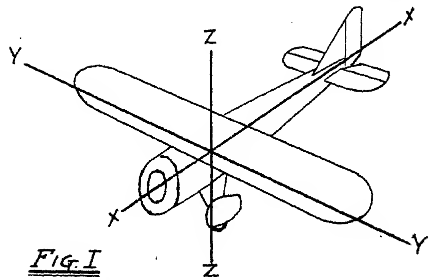


FIG. I

The axis X - X is called the longitudinal or "X" axis, the axis Z - Z the vertical or "Z" axis, and the axis Y - Y the lateral or transverse, or "Y" axis. These axes are considered as intersecting each other at the center of gravity of the airplane, and to change its attitude it must rotate about one or more of these axes. It may be made to rotate about any of them or all three at once, at the will of the pilot, by manipulation of the proper controls.

Rotation about the lateral axis is caused by moving the elevators up or down, or by changing the setting of the stabilizer, if the stabilizer is adjustable in flight. These movements produce climbing or diving.

Rotation about the vertical axis is produced by moving the rudder to one side or the other, causing the airplane to turn.

Rotation about the longitudinal axis, or banking, is produced by operating the ailerons one way or the other.

Except in special maneuvers, it is seldom that only one control is used at a time. For instance, in making a normal turn, the rudder is moved to start the turn, the ailerons to bank the ship properly and prevent skidding, and the elevator pulled up slightly to keep the nose from dropping.

As the attitude of the ship changes, the axes are considered as changing with it. In other words, the vertical axis is vertical only when the airplane is in normal, straight flight with the wing level, the longitudinal axis is horizontal only when the plane is neither climbing nor diving, and the lateral axis is horizontal only when the ship is not banked. Thus it may be seen that if the ship rotates about any one of the three axes, the other two must change their position.

The three axes will be discussed further under "Stability".

THE FORCES IN FLIGHT

There are four major forces on an airplane in flight. These four are divided into two pairs, one pair acting vertically, the other horizontally. To maintain a certain speed in a straight, horizontal line, the forces in each pair must exactly balance each other. An increase or decrease of either force in a pair without a corresponding increase or decrease of the other force in the same pair, will change the flight path of the airplane, if its attitude is not changed.

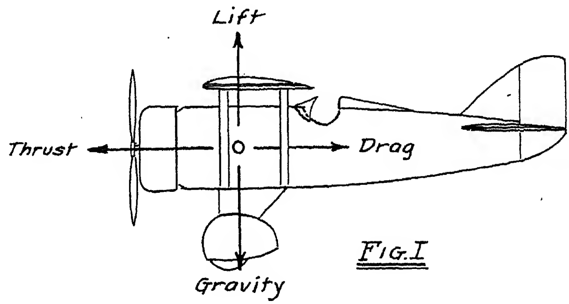


FIG. I

Fig. I illustrates the four main forces, each of which, with the exception of THRUST, is composed of a number of smaller forces. It is more convenient to consider these smaller forces as combined into one when considering the airplane as a whole. For example, the main force referred to as DRAG is the sum of the drag, or resistance of all the various parts exposed to the air - wings, wheels, struts, wires, fuselage, empennage, etc. The drag of these parts is scattered all over the airplane, but the effect is the same as if it were concentrated at one point, called the CENTER OF RESISTANCE or CENTER OF DRAG.

LIFT is the upward force produced by moving the airplane through the air. Practically all of the lift is due to the wings, though there may be small additional amounts from the fuselage, special types of wing bracing, etc. On the other hand, certain parts, such as (in most airplanes) the stabilizer, may exert a negative lift - or downward force. This will be explained further in the section on stability. It is practically impossible to determine all of the smaller vertical forces without testing a model of the complete airplane in a wind tunnel, and then the designer, as a rule, does not bother with the individual forces, but considers only the total.

GRAVITY is the downward pull of the earth, or the weight of the complete airplane. In considering the ship as a whole, the weights are considered as concentrated at one point - the CENTER OF GRAVITY.

THRUST is the pull, in a tractor airplane, or the push, in a "pusher" of the propeller or propellers. In an airplane with one engine it acts along the centerline, or axis of rotation, of the propeller. In a multi-engine arrangement, it is considered as concentrated at one point, in the same manner as the other forces.

STABILITY

Stability may be defined as the tendency of a body to return to its state of rest, or motion in a given line, when acted upon by an outside force.

A cone resting upon its base is stable. If it is tilted slightly and released, it will immediately fall back upon its base. If resting upon its apex it is unstable, as the slightest movement will result in its toppling over. In fact, it is almost impossible to balance it so that it will remain standing on the point.

Another illustration of stability is a pendulum. If moved from its vertical position, it tends to return so vigorously that it swings past the vertical and requires several oscillations before it becomes stationary again.

A third illustration, which involves the principle of the pendulum, is a sailboat with a heavy keel. If a puff of wind strikes the sail, the boat will heel over until it spills the wind from the sails and then come back to a position of equilibrium or balance between the force of the wind and the weight of the keel.

Stability in an airplane is its tendency to return to normal flight when put into any unusual position, and no ship will be licensed by the Civil Aeronautics Authority until it has been shown to possess this characteristic.

Since an airplane may rotate about any of its three axes it follows that there are three types of stability. Stability around the transverse or lateral axis is called longitudinal stability. A ship which is stable longitudinally will recover from a dive or a stall without effort on the part of the pilot.

Stability with respect to the longitudinal axis is called lateral stability, since the tendency is for the lateral axis to remain horizontal. A laterally stable airplane will return to a level position of its own accord if thrown into a bank by a gust of air (an air "bump") or other force.

Stability around the vertical axis is known as directional stability, and tends to restore the ship to a straight-ahead course if any force has turned it to one side or the other.

The complete and technical study of stability is a large subject, not essential for the mechanic. The rudiments, however, are comparatively simple and should be understood to make intelligent rigging possible.

LONGITUDINAL STABILITY

This is mentioned first because it is the most important of the three. If an airplane will not recover automatically from a stall or too steep a climb, it is decidedly unsafe. This type of

STABILITY
(continued)

stability is not extremely difficult to secure, provided the design of the ship in general is not freakish. Without going into too much detail, the procedure is to balance the ship so that the center of gravity is slightly ahead of the center of pressure of the wings. This means, of course, that the airplane is noseheavy and has a tendency to dive while flying. This tendency is counteracted by setting the stabilizer so that there is just enough down

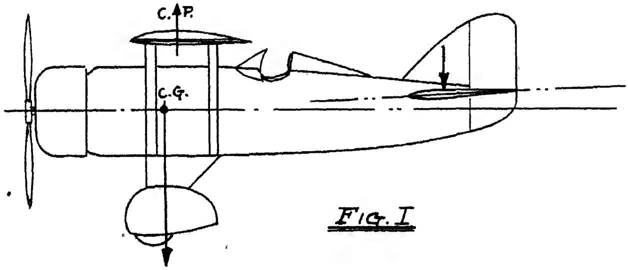


Fig. I

load on it to hold the ship level. In other words, to have a negative tail. See Fig. I.

Since, as shown in the discussion of the airfoil, the lift increases as the square of the speed, the downward force, or negative lift, on the tail, which is an airfoil, increases and decreases with the velocity of the airplane. Thus, if the stabilizer is set so as to hold the ship level at cruising speed and the motor is suddenly cut, the speed will decrease and likewise the downward force on the tail. This will allow the nose to drop, which will cause the speed to increase until there is sufficient negative lift built up on the tail to pull the nose up again. This oscillation down and up will continue, growing less each time, until, in a properly designed ship, equilibrium, or balance, is reached, and the ship remains in a normal glide. All of this takes place without touching any of the controls, and demonstrates that the ship is inherently stable longitudinally.

LATERAL STABILITY

Lateral stability is ordinarily obtained by the use of a dihedral angle in the wing structure. It is commonly believed that dihedral produces this stability because of an increase in the effective span of the wing which is down, as shown in Fig. II. The real reason, however, can be much better understood by making a

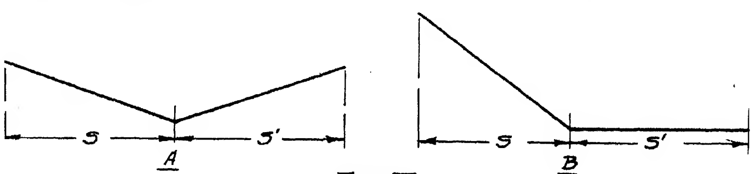


Fig. II

STABILITY
(continued)

cardboard model similar to that shown in Fig. III. When one wing of an airplane is down, the ship tends to sideslip toward the low wing. It is also, of course, moving forward at the same time.

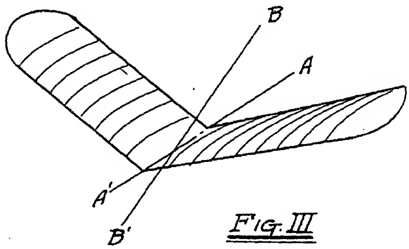


FIG. III

This causes the low wing to strike the air at a much higher angle of attack than the high one. Since lift increases with an increase in the angle of attack, the lift of the lower wing is temporarily greater than that of the higher and this causes the ship to level itself out. By moving the model wing along a line B-B' instead of the normal flight path A-A', thus simulating a side slip, it may be readily seen that in extreme cases the air will strike the top of the high wing. Sweepback has a similar effect but it is not nearly as pronounced as that of dihedral.

DIRECTIONAL STABILITY

This is the hardest to secure. It is obtained by proper distribution of fin surface, and in this surface is included the whole fuselage, vertical tail, and landing gear or floats. By having enough fin surface to the rear of the c.g. the plane is kept on its course in the same way that the feathers of an arrow keep it straight. When additional fin area is put forward of the c.g. as when wheels are replaced with floats, it is often necessary to increase the size of the vertical tail surfaces or to add an auxiliary fin, such as is often seen below the fuselage on seaplanes.

CIVIL AIR REGULATIONS REQUIREMENTS

Before licensing any airplane, the Civil Air Regulations require the manufacturer to demonstrate that it possesses inherent stability about all three axes. The demonstration consists of abruptly moving the controls so as to throw the ship into some abnormal position and then letting go of the controls and allowing the ship to right itself without assistance from the pilot. The airplane, if it weighs less than 4000 lbs., must also be put into a spin, and held there for six turns, after which it must come out within a turn and a half with the controls in neutral.

Making these tests was once a rather hazardous job and many pilots were killed trying out new designs. It is still not looked upon with favor by the insurance companies, but wind tunnel research has eliminated much of the uncertainty which once existed and it will probably not be long before all characteristics of a new design can be accurately predicted long before it is built.

PERFORMANCE

It is not necessary for the mechanic to be able to calculate the performance of an airplane. However, it is well for him to have a general idea of the factors affecting it without going into too many technical details.

Performance includes in general the landing or stalling speed, the high speed, the rate of climb and the ceiling. From tests on a wind tunnel model, these can be predicted with great accuracy, particularly the first three. It is also possible to calculate the performance from nothing more than a drawing but the percentage of error is likely to be much greater than when the figures are based on wind tunnel tests of a complete model.

The stalling speed is obtained by use of the airfoil characteristics, using the maximum lift coefficient. The formula has already been given under THE AIRFOIL, but it may be repeated. If W = gross weight of the airplane, A = the wing area in square feet, V = the speed in miles per hr. and K_y the lift coefficient, $W = K_y A V^2$ and $V = \sqrt{\frac{W}{K_y A}}$

The high speed is much more complicated. Unless tests on a complete model are available, the drag of each part must be calculated, using drag coefficients obtained by tests on objects similar in shape to the parts of the ship in question. The wing drag is, of course, obtained from the chart of airfoil characteristics and is usually kept separate from the drag of the rest of the airplane. The latter is called parasite drag since it contributes nothing to the lift. Having obtained the total drag R at a given speed, by adding the wing drag and the parasite drag, the horsepower must be obtained from the power curve of the engine.

Since the propeller is only about 75% efficient, the actual horsepower of the engine must be reduced by 25%. This is the H.P. available. The formula for the H.P. required at any speed is $H.P. = \frac{R \times V}{375}$. It will be noted that since R is the total drag at 1 mile per hr. times the speed squared (or V^2), the horsepower required varies as the cube of the speed. This is why increasing engine horsepower often has disappointing results as regards speed. If the horsepower in a given plane is doubled and the plane is not changed in any way, the top speed will increase only about 26%. To double the speed of the plane, without changing its lines, an engine of the same frontal area but with eight times as much power would have to be installed - since the cube of 2 is 8.

Of course, down to a certain point the slower the plane flies the less power is required to maintain level flight. The best speed for climbing is that which requires the least H.P. for level flight. The stalling speed plus 1/3 the difference between the stalling speed and the top speed is usually approximately the best speed for climbing. The H.P. required for this speed subtracted from the total H.P. leaves the reserve H.P. available for climb. Since one H.P. is 33,000 ft. lbs. per min. the rate of climb in feet per minute is $\frac{\text{Reserve H.P.} \times 33{,}000}{\text{Weight of Airplane}}$.

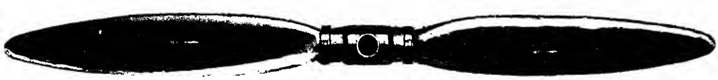
PROPELLER TORQUE

If the propeller of an airplane were as large as the plane itself, the plane would spin around in one direction and the propeller in the other. Or, if the propeller of any plane were held stationary and the engine continued to run, the plane would revolve in a direction opposite to that in which the propeller normally revolves. Of course, both of these conditions are impossible, but actually the resistance of the air tends to hold the propeller stationary which makes the airplane tend to revolve. This tendency of the airplane to rotate about the axis of the propeller is called propeller torque. If nothing is done to offset this torque, one wing of the airplane tries to go down while in flight, and the pilot must constantly hold the wing up with the aileron. It is just as though a weight were hung on the end of one wing, and hence is called wing heaviness.

In order to remove the necessity of holding the stick to one side, the lift on the "heavy" side is increased by warping the tip of the wing and increasing the angle of attack. This is called wash-in. An alternate method is to warp the other wing so that the angle is decreased at the tip, which is called wash-out. In ships equipped with American engines which rotate in a clockwise direction as viewed from the pilot's seat, in a single-engine tractor plane, the torque makes the left wing of the ship go down, or tends to rotate the airplane in a counter-clockwise direction, so the left wing is washed in or the right washed out, or both.

However, increasing the angle of the left wing tip increases its drag as well as its lift, so the airplane now tends to turn to the left. To eliminate this tendency, the leading edge of the vertical fin is set over to the left which tends to turn the airplane to the right. Otherwise the pilot will have to apply a constant pressure on the right rudder pedal. Offsetting the fin also takes care of the twist given to the propeller slipstream by the rotation of the propeller. If the fin is in line with the center of the fuselage, and also above the propeller axis as is usually the case, the slipstream strikes it on the left side which tends to push the tail to the right or make the ship turn to the left. This adds to the effect of the wash-in.

The offsetting of the fin cannot be exactly correct except for one speed. When the engine is wide open and the ship is going slowly, as in taking off or climbing steeply, the relative velocity of the slipstream as compared with the velocity of the airplane is high. At the maximum speed of the airplane the difference between the velocity of the slipstream and the velocity of the airplane is small. Hence the offset is made so as to cause exact correction at cruising speed.



CONTROLS

There are three sets of control surfaces in the airplane which rotate it about its three axes respectively. The ailerons rotate the ship around its longitudinal axis, the elevators about its lateral axis and the rudder or rudders about its vertical axis. These three may be called flight controls. In addition there are auxiliary controls for purposes of trimming or balancing the airplane so that it can be flown indefinitely "hands off" or without touching the control operating mechanism. In this class are the stabilizer and fin adjustments and trimming tabs on rudder, elevators, and occasionally on ailerons. They may be called adjustable controls. There is still a third group which is used only for special occasions. This includes the devices for operating the wing flaps and retractable landing gear. There are also the engine controls which, however, do not affect the behavior of the ship except from

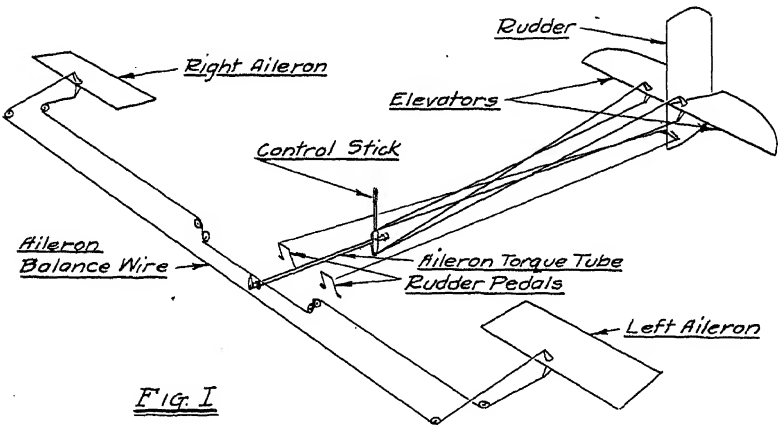


FIG. I

the standpoint of changing the power delivered by the engine. We are not concerned with most of the third group here.

FLIGHT CONTROLS

The operation of the first group is essentially the same in all airplanes as flying is automatic and instinctive on the part of the pilot, calling for quick reactions and allowing no time to figure out a procedure with which he is unfamiliar. All the other controls vary in different models as there is usually plenty of time to make the necessary adjustments. Fig. I shows a diagram of a typical control system.

In small ships which are likely to be maneuvered quickly, the ailerons are controlled by a stick as shown. In larger or cabin types a wheel is used to operate the ailerons. The wheel type was once called the Deperdussin or "Dep" control, after its inventor. However, the wheel leads to no confusion when a pilot changes to it from the stick type for if the wheel is grasped at the top the move-

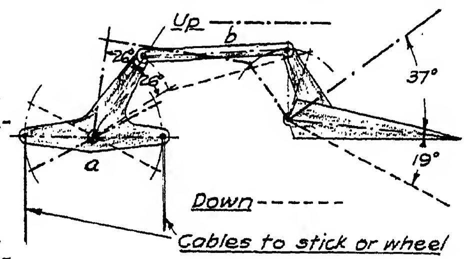
CONTROLS
(continued)

ment is identical with that of the stick.

The diagram in Fig. I is standard only with respect to the motions involved. Every designer has different ideas about the actual operating mechanism. Some use wires, some use torque tubes, some use push and pull rods and some a combination of the three.

DIFFERENTIAL CONTROLS

These are controls which, for the same amount of motion of the stick or wheel, move further in one direction than the other. The principle is frequently used on ailerons, rarely on the elevators, and practically never on the rudder. Differential ailerons are those in which the aileron moving down swings through a relatively small angle, such as 15°, while the one moving up swings through a relatively large angle, such as, perhaps, 30°. The purpose of this arrangement is to improve lateral control at stalling speeds and to eliminate yaw caused by the down aileron. It may be used with any type of balance, though less needed with the Frise balance discussed below.



The sketch to the right shows the principle employed in obtaining differential action of the ailerons. In practice, the horn "a" lies flat in the wing, and the connecting tube, "b", is provided with universal joints at each end. The horn "a" is shown in the sketch turned up on edge, so to speak, so that the relationship between it and the aileron horn may be seen. While a cable control to the stick or wheel is indicated, a push-pull tube, a torque tube, or any other conventional type of operating mechanism may be employed. The basic principle in all, however, is that shown above.

BALANCED CONTROL SURFACES

To lessen the force required of the pilot in operating the control surfaces, they are often balanced, usually by having a portion of the surface extend forward beyond the hinge line. The various types of balances with the names of each are shown in Fig. II.

The overhang type of balance is not regarded with great favor any more, particularly for use on ailerons, as the turbulence of the air at the end of a wing causes vibration and excessive loads.

The Handley-Page type is popular, especially on elevators and rudders, and is sometimes found on ailerons.

The Frise balance is adapted only to ailerons and is considered the best for this purpose. It will be noted that when the aileron is up the nose of the balance projects below the wing. This sets up a drag on the side on which the aileron is up which counter-

CONTROLS
(continued)

acts the drag of the aileron which is down, thus eliminating the tendency of the ship to yaw or turn toward the down aileron.

The paddle balance consists of a small auxiliary airfoil mounted ahead of the hinge. Its drag is high and it is seldom used.

The tab balance is not strictly a balance but has the same effect. It is a small surface at the trailing edge of the main one. It was originally designed for use on very large ships where the effort required to move the main surface was too great. The small

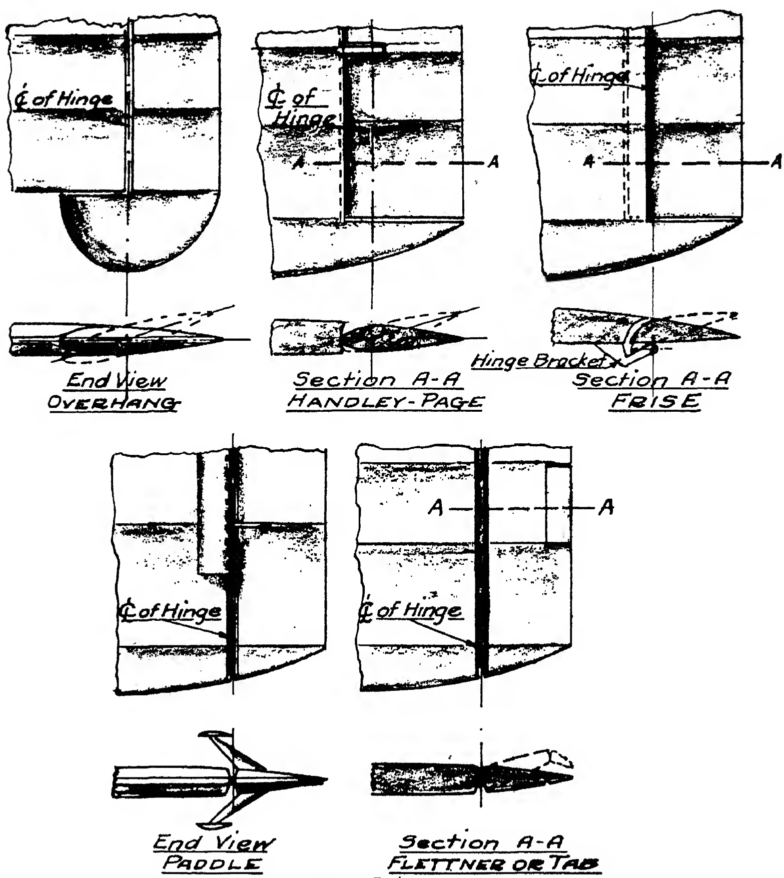


FIG. II

CONTROLS
(continued)

surface is connected to the controls in the cockpit but works in a direction opposite to that of the main surface. In other words, if the rear edge of the small surface is moved to the right it creates a lifting force which moves the rear of the main surface to the left. It is not used so much as a balance but is being widely used to replace adjustable stabilizers and fins. When so used, it is called a trimming tab and will be discussed further below.

ADJUSTMENTS FOR TRIMMING

Any change in the position of the c.g. affects the balance of the airplane, making it noseheavy or tailheavy as the case may be. A change of engine speed has the same effect in most ships. These changes would mean a constant effort on the part of the pilot to maintain straight and level flight if some means were not provided to take care of them. It is surprising how soon one tires of pushing ahead on the stick in a tailheavy airplane, or of holding rudder on one which has not the proper compensation for propeller torque. And in blind flying it is not only annoying but dangerous.

On all but the smallest ships, some method is provided for trimming or balancing the ship longitudinally while in flight. Many models provide for directional trim, and some even take care of slight wingheaviness. The method of trimming varies. The cheapest is usually the "bungee" which consists of an adjustable spring attached to the stick or rudder pedal to pull it in the direction toward which the pilot would have to hold the control. At the same time, due to the elasticity of the spring, the pilot can move the control in the opposite direction if desired. Civil Air Regulations with respect to bungees are quoted below:

"Spring devices. The use of springs in the control system either as a return mechanism or as an auxiliary mechanism for assisting the pilot (bungee device) is prohibited except under the following conditions:

(a) The airplane shall be satisfactorily maneuverable and controllable and free from flutter under all conditions with and without the use of the spring device.

(b) In all cases the spring mechanism shall be of a type and design satisfactory to the Secretary.

(c) Rubber cord shall not be used for this purpose."

The most common means of taking care of longitudinal equilibrium is the adjustable stabilizer. The stabilizer is pivoted at either its front or rear beam, usually the latter. The beam which is not pivoted is attached to a mechanism which moves it up or down a limited amount at the will of the pilot. The mechanism may consist of a push and pull rod operated by a lever which may be locked in a number of positions, a pair of tie rods with a similar lever, a torque tube operating a screw adjustment by means of a crank or an endless cable around two drums, one of which is mounted on the screw adjustment at the tail and the other fastened to a wheel or crank in the cockpit. The screw adjustment is preferred as it is self-locking and provides a finer adjustment. If the wheel or crank is located so that its axis is parallel to the elevator hinge its movement should correspond to that of the stick. That is, if

CONTROLS
(continued)

the top of the wheel is moved forward, the ship should tend to become noseheavy. A diagram of a typical adjustment is shown in Fig. III.

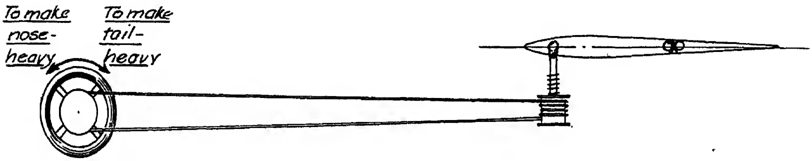


FIG. III

If the wheel or crank is located so that its axis is in some other plane, as, for example, on the ceiling of the cabin, the direction of rotation is unimportant. But in any case it should be plainly marked.

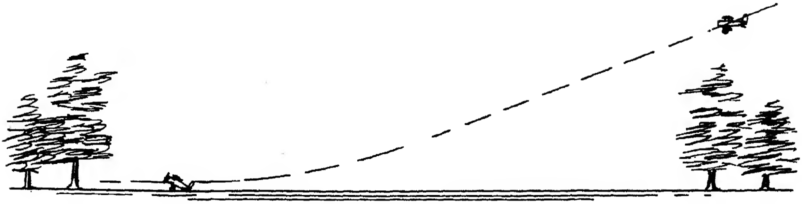
In order to mount the stabilizer rigidly, many ships are now using trimming tabs, similar to the Flettner balance, in the elevators. Also, to provide directional trimming, a tab is put on the rudder. See the illustration of the Sikorsky rudder under "ALUMINUM". Tabs may also be put in the ailerons, for lateral trim. These tabs are usually operated by some sort of screw adjustment controlled by cables from the cockpit. If the ship is noseheavy, the trailing edge of the elevator tab is moved down, causing the elevators to go up slightly.

WING FLAPS

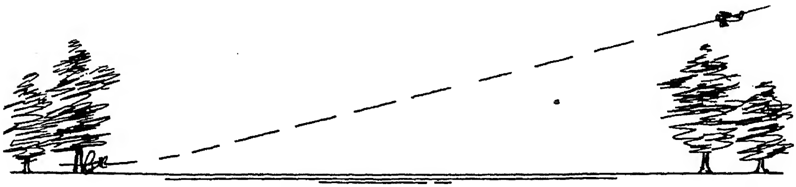
In order to cut down landing speed, many airplanes are now equipped with flaps on the rear of the wing. By pulling these down, the camber of the wing is increased. This increases the lift coefficient and also the drag coefficient. Increasing the drag produces a steeper glide, and hence the ability to glide into a smaller field. Increasing the lift coefficient makes it possible, of course, to land at a lower speed. Fig. IV illustrates the effect of steepening the glide.

There are three general types of flaps. These are illustrated in Fig. V on the following page. As a rule, the flaps extend along the portion of the wing between the fuselage and the aileron. It will be noted that the Fowler flap increases not only the camber, but also the area of the wing. When this flap is extended, it is carried on supports fastened to the rear portion of the wing. In its closed or retracted position it fits into a recess as indicated, so that the standard airfoil section is maintained. The supports do not retract, but since they are in line with the air stream, offer no resistance. Certain models of the Lockheed use Fowler flaps.

CONTROLS
(continued)



With Flaps



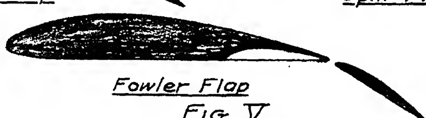
Without Flaps

Fig. IV

Flaps are sometimes combined with slots in the nose of the wing, as shown in Fig. VI. Slots may be fixed or permanently open, or they may be movable. In the latter case a portion of the nose of the wing is carried on hinged arms which permit this portion to move forward and upward automatically when the wing approaches a stall. In normal flight the slot is closed and the airfoil retains its standard shape. Slots tend to eliminate "burbling" until a high angle of attack - 30° or more - is reached, thus preventing a stall. There are innumerable combinations and variations of slots and flaps, most of which improve landing characteristics to some extent. Some arrangements claim to increase the lift nearly 100%. All but the very cheapest airplanes use some type of flap. Slots are less common.

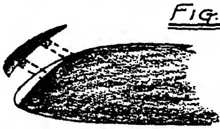
Simple Flap

Split Flap

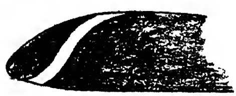


Fowler Flap

Fig. V



Movable Slot



Fixed Slot

Fig VI

WIRE AND CABLE

There are four kinds of wire and cable used in airplanes for the transmission of loads. They will be taken up individually.

TINNED AIRCRAFT WIRE

This is also frequently referred to as PIANO WIRE. It is solid, high strength steel wire and is obtainable in sizes varying from .032" to .306", and strength from 225 lbs. to 14,000 lbs. The more common sizes are given in the table to the right

This wire is tinned for the purposes of preventing rust and making it easy to solder. It was once used widely for internal bracing of wings and fuselages, but due to the likelihood of breakage in the loop of a terminal, its use for this purpose has been practically discontinued in favor of tierods, which are discussed in subsequent pages. It is still commonly employed for cowl pins. (See Cowl Fastenings). If used for bracing, the terminals or "eyes" are made by doubling the wire back on itself, sliding a ferrule of the proper size onto the doubled portion and bending the short end over the ferrule. The whole terminal is then soldered, preferably by dipping into melted solder. Fig. I illustrates a terminal made in this manner. The ferrule is purchased already coiled. It is practically impossible for a mechanic to make one properly. See instruction sheet "How To Make An Eye Terminal In Piano Wire."

TINNED AIRCRAFT WIRE

Roebling Gage No.	Diam. Inch	Breaking Strength Lbs.
10	.135	3,290
11	.120	2,670
12	.105	2,090
13	.091	1,600
14	.080	1,250
15	.072	1,040
16	.062	775
17	.054	600
18	.047	460

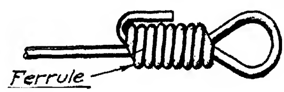


Fig. I

NON-FLEXIBLE CABLE

This type of cable was once used extensively for the external bracing of wings and tail surfaces. Like the piano wire, it has also been almost entirely replaced by tierods, not because of breakage but because tierods, if of the streamline type, offer much less resistance. The "construction" of this cable is called "nineteen" wire or "1 x 19". See Fig. II. It may be well at this point to explain the meaning of "construction" when used in this sense. A group of wires laid in a helix around a center wire, or core, is called a "strand". A number of strands may be laid helically around another strand, forming a flexible cable. The first figure in the description of the cable gives the number of strands, the second gives the number of wires in each strand. Thus "7 x 19" means the cable has seven strands, each of which contains nineteen wires. The "construction" of this cable would be called 7 x 19. The 1 x 19 cable is not very flexible, and is useful only for bracing, holding safety belts, etc. It is made of high carbon

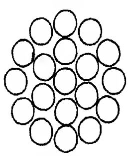


Fig. II

WIRE AND CABLE
(continued)

steel, galvanized, and of stainless steel. It is also fabricated either "Preformed" or "Non-preformed". See Fig. III. In preformed cable, the individual wires or strands are formed into the helical shape they will take in the finished cable before they are laid together. This increases flexibility, tends to prevent sudden untwisting when the cable is cut, makes splicing easier, lessens kinking, and relieves internal strains. A table of sizes and corresponding strengths is given below. This and succeeding tables, with other data on cables, is supplied by the Macwhite Company, manufacturers of cable and tierods. The diameter of the cable is the diameter of the circle which surrounds it. Care should be taken in measuring, particularly in regard to 7 x 7 or 7 x 19 cable, to hold the calipers as shown in "A", Fig. IV. It is well to rotate the calipers around the cable to make sure that the diameter of the enclosing circle has been obtained. Before cutting the cable, especially if it is not preformed, it should be served or tightly wrapped with soft iron, copper, or brass wire, for a distance of 1/4" to 1/2" on each side of the point where it is to be cut. Otherwise, it will untwist the instant it is severed and render handling or splicing difficult or impossible. Terminals in 1 x 19 cable are of the wrapped and soldered type. See Instruction Sheet "How to Make a Wrapped Terminal."

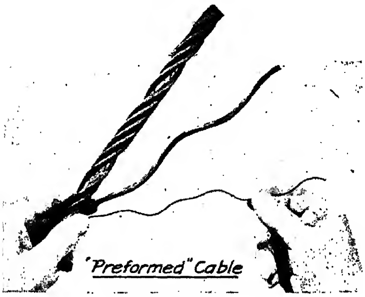


FIG. III

Diam. in Inches	Minimum Breaking Strength in Lbs. Galvanized	Stainless
1/32*	185	150
1/16	500	550
3/32	1,100	1,200
1/8	2,100	2,100
5/32	3,200	3,300
3/16	4,600	4,700
7/32	6,100	6,300
1/4	8,000	8,200
5/16	12,500	12,500

*1/32 has seven wires

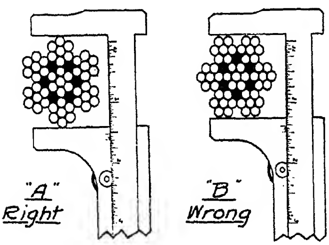


FIG. IV

FLEXIBLE CABLE

The construction of this cable is 7 x 7 and it is often called "control cable" along with the 7 x 19 described in the next paragraph. Fig. V shows the cross-section. It is used for control cables where the bends around pulleys are not too sharp. It is not as flexible as the 7 x 19, but may be obtained in smaller sizes. It is supplied in tinned or stainless steel, preformed and non-preformed. The table given here gives the standard sizes. Terminals in 1/16" cable may be of the wrapped type, but for control wires the Civil Air

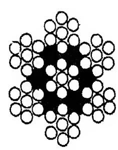


FIG. V

WIRE AND CABLE
(continued)

Regulations require either the Navy tuck splice or the Roebling roll splice. See Instruction Sheets on these two.

7 x 7 FLEXIBLE CABLE

Diam. in Inches	Minimum Breaking Strength in Lbs. Galvanized	Stainless
1/16	480	480
3/32	920	1,000
1/8	1,350	1,700
5/32	2,600	2,600
3/16	3,200	3,200
7/32	4,600	4,800
1/4	5,800	6,100
5/16	9,200	9,100

EXTRA-FLEXIBLE CABLE

This is the best cable for controls, especially where it must run on pulleys. The construction is 7 x 19 and is shown in Fig. VI. This cable is manufactured, as the 7 x 7, in tinned steel or stainless, preformed and non-preformed. Terminals are made in the same manner as in the 7 x 7. The standard sizes are given in the table below. It will be noted that the smallest diameter listed is 1/8". If it were made smaller, the wires would be so fine that they would wear out and cause the cable to fray too quickly.

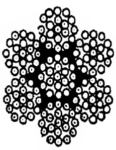
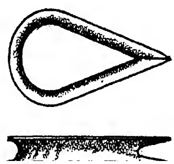


FIG. VI

THIMBLES, BUSHINGS, SHACKLES

Terminals in cable are always made around a thimble or bushing, usually the former, though if the eye of the terminal passes directly around a bolt, the bushing makes an excellent arrangement. The two devices are shown in Figs. VII and VIII respectively.



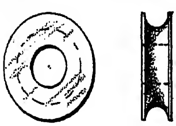
THIMBLE

FIG. VII

7 x 19 EXTRA-FLEXIBLE CABLE

Diam. in Inches	Minimum Breaking Strength in Lbs. Galvanized	Stainless
1/8	2,000	1,900
5/32	2,800	2,800
3/16	4,200	3,900
7/32	5,600	5,200
1/4	7,000	6,600
9/32	8,000	8,000
5/16	9,800	9,600

Where cables are attached to fittings consisting of a single plate, a shackle, sometimes called a CLEVIS, is ordinarily used. See Fig. IX. These may be purchased in standard sizes and may usually be hooked through the thimble after the eye-splice is made. Care should be taken before making the splice, however, that the flat part of the shackle is not too wide to go through the thimble without distorting the eye, and also that the opening for the fitting is large enough for the thimble to pass through without spreading the shackle apart. When possible, the eye should be made up on the shackle.



BUSHING

FIG. VIII

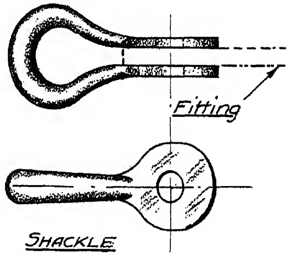


FIG. IX

PULLEYS AND FAIRLEADS

Wherever a control wire changes direction it must pass over a pulley or through a fairlead. If the change in direction is more than 15° a pulley should always be used.

Fig. I shows pulleys, one with a ball bearing and one with plain bearing, and Fig. II shows two types of fairleads. The pulleys and fairleads are made of "Formica", which is a laminated product of synthetic resins and paper or fabric which has been cured into a hard, compact material by heat and pressure. The illustrations are supplied by the courtesy of the Formica Insulation Company.

Fig. I

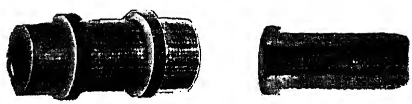
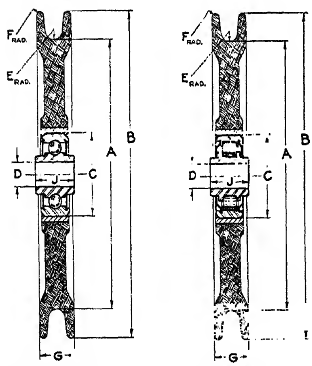


Fig. II



Ball Bearing Pulley   Roller Bearing Pulley

Fig. III

A section of pulleys with Norma-Hoffman ball and roller bearings is shown in Fig. III. The radius "E" is ordinarily either 3/64 for very small cable or 7/64 for the larger sizes. "D" is the diameter of the bolt which is either No. 10 or 1/4", "J", the width of bearing, is either .297" or .484", "A" varies from 7/8" to 2-7/8", "B" from 1-1/4" to 3-1/2", "C" from .625" to .9014", and "G" is either 17/64 or 7/16.

PULLEYS AND FAIRLEADS
(continued)

Another pulley with a roller bearing made by S.K.F is shown in Fig. IV. Pulleys equipped with ball or roller bearings, of course ease up the operation of the controls. Also, the larger the pulley, within reason, the better, as the greater the radius around which the cable is bent the longer it will last and the easier it will move. Pulleys should be guarded so that it is impossible for the cable to be forced off with the hands. Fig. V shows a typical guard.

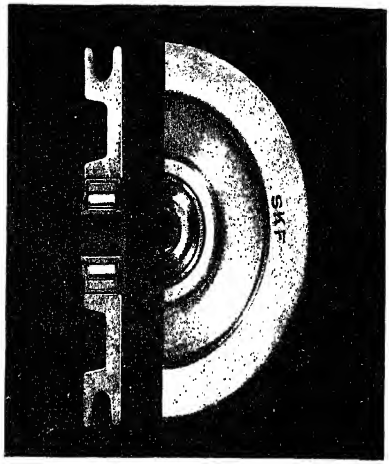


Fig. IV

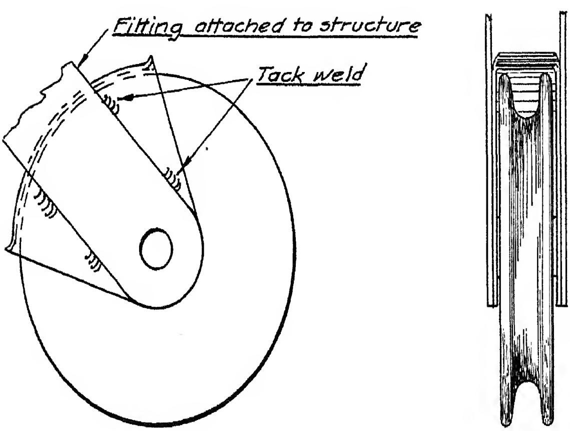
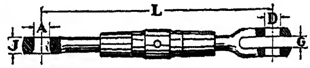


FIG. V

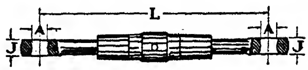
TURNBUCKLES

The standard means of adjustment for wires and cables, whether used as braces or to operate controls, is the turnbuckle. A turnbuckle consists of three parts, a barrel and two ends, one of which has a right hand thread, the other a left hand thread. One end is made with a rounded hole to fit the loop of the cable, the other may be a forked, or female, end, a pin eye, or male, end, or a cable eye the same as the other. The right hand thread is always on the forked or pin end. Of course, when two cable ends are used, there is no way of determining the threads without trying them.



Type AN 130

Type AN 135



Type AN 140

AN NUMBER Type 130	AN NUMBER Type 135	AN NUMBER Type 140	STRENGTH POUNDS	L	A	D	J	G
AN130-8S	AN135-8S	AN140-8S	800	4½"	.188"	.188"	.125"	.109"
AN130-16S	AN135-16S	AN140-16S	1600	4½"	.219"	.188"	.188"	.150"
AN130-21S	AN135-21S	AN140-21S	2100	4½"	.219"	.188"	.188"	.150"
AN130-32S	AN135-32S	AN140-32S	3200	4½"	.281"	.250"	.219"	.203"
AN130-46S	AN135-46S	AN140-46S	4600	4½"	.313"	.313"	.281"	.203"
AN130-16L	AN135-16L	AN140-16L	1600	8"	.219"	.188"	.188"	.150"
AN130-21L	AN135-21L	AN140-21L	2100	8"	.219"	.188"	.188"	.150"
AN130-32L	AN135-32L	AN140-32L	3200	8"	.281"	.250"	.219"	.203"
AN130-46L	AN135-46L	AN140-46L	4600	8"	.313"	.313"	.281"	.203"
AN130-61L	AN135-61L	AN140-61L	6100	8"	.344"	.375"	.281"	.203"
AN130-80L	AN135-80L	AN140-80L	8000	8"	.375"	.375"	.328"	.266"
AN130-125L	AN135-125L	AN140-125L	12500	9"	.469"	.438"	.375"	.344"
AN130-175L	AN135-175L	AN140-175L	17500	9½"	.563"	.500"	.469"	.406"

The three types are shown in Fig. I together with a table of dimensions and strengths. The numbers "AN 130" etc. refer to the Army-Navy specification number.

The ends of turnbuckles are made of steel, cadmium-plated, and the barrels may be either steel or bronze. Bronze is better on seaplanes. In either case, the threads should be covered with light grease before the turnbuckle is put together.

If turnbuckles have become rusted so that they cannot be loosened, it is usually possible to get them apart by hammering the barrel on a steel block, meanwhile rotating the turnbuckle. When this procedure has become necessary, the turnbuckle should not be used again.

In adjusting turnbuckles pliers should never be used to grip the barrel or the ends. A small punch or other stiff rod should be inserted in the hole in the barrel and another in the eye, and

TURNBUCKLES
(continued)

the barrel rotated by this means.

Turnbuckles should be safetied with 18 ga. or 20 ga. wire of copper, brass, or galvanized soft steel. The proper method of using this wire is shown in Fig. II. Note that the slope of the

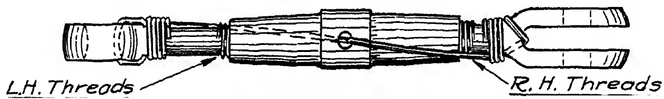
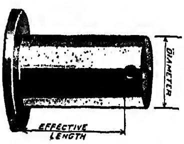


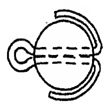
FIG. II

wire tends to tighten the turnbuckle. Not more than three threads should be exposed at either end.

Turnbuckles are attached to fittings at the forked end with bolts and castellated nuts properly cottered, if they are used on control cables. Where they are used on brace wires it is permissible to attach them by means of clevis pins. Clevis pins are made of alloy steel of high strength. They come in sizes to fit the standard turnbuckles and tie rod terminals. They are kept from falling out by means of cotter pins.

Fig. III-A shows a standard clevis pin and Fig. III-B illustrates the proper method of bending the cotter pin. Brass cotter pins should be used on seaplanes.





A B

FIG. III

SPECIAL TOOLS FOR WIRE AND CABLE WORK

it is possible to make eyes in wire and cable without special tools, the work will be greatly expedited and a much better job will result if the proper devices are used. Any mechanic can make those shown, though the splicing clamp (Fig. II) may have to be modified, if home-made, depending on the materials available from which to make it.

Fig. I illustrates a bending jig for piano wire. Three pieces of steel rod are threaded, and screwed into holes tapped in a block of steel or other metal. The size of the rods and the distance between them depends upon the size of the wire to be bent. In general, for wires of 14 or 16 gage, 1/4" or 5/16" rods separated about 1/8" will be found satisfactory. For the use of this jig, see Instruction Sheet on making terminals in piano wire.

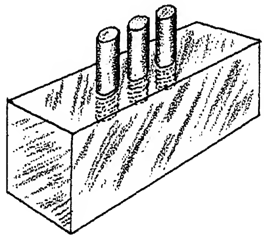


FIG. I

SPLICING CLAMP

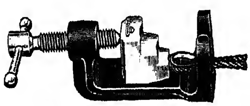


Fig. II shows a clamp for holding either flexible or non-flexible cable while making an eye splice. A necessary adjunct to this work is an awl or marline-spike such as is shown in Fig. III. This may be made from screwdriver or from drill-rod with the handle put on afterward. Or it may be purchased from any aeronautical supply house.

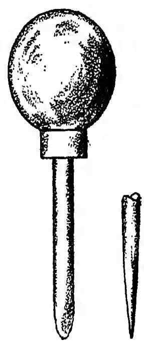


FIG. III

For serving tucked or Roebling splices with cord, a serving maul, made of a piece of brass tubing soldered to a piece of brass rod will expedite the job, once the splicer has become familiar with its use. The cord is started on the cable, then the inside of the tube is laid on the cable, the serving cord carried around the tube and wrapped around the shank of the maul several times. The friction of the cord sliding around the shank keeps the serving tight.

FIG. IV

HOW TO MAKE AN EYE TERMINAL IN PIANO WIRE

As stated previously, piano wire is no longer installed in new ships for bracing. However, there are a number of airplanes still flying which employ this material and on which repairs must be made. Also, it is sometimes used for other purposes, such as safety belt attachments and the like.

MATERIAL: Piano wire, ferrule, solder, soldering flux.

TOOLS: Bending jig, wire cutters, pliers, vise, soldering iron, blow-torch (unless electric soldering iron is used).

PROCEDURE:

1. Clamp bending jig in vise.

2. Slip ferrule on wire and slide down past point where eye is made.

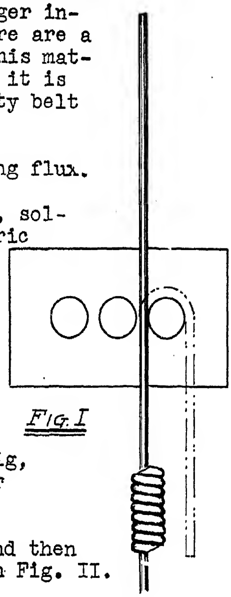


Fig. I

3. Place wire between two of the pins on the jig, leaving several inches of extra length for making final bend. See Fig. I.

4. Bend free end of wire 180° around end pin and then remove from jig and replace it as shown in Fig. II.

5. Bend each end in opposite direction until it is approximately parallel to the centerline of the three pins. When the ends spring back, the angle of bend will be about 45°, which is desired. If the angle is less than 45° the bend should be increased. The wire will then appear as in Fig. III.

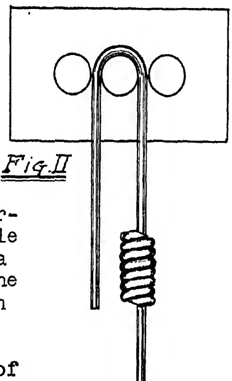


Fig. II

6. Remove wire from bending jig, pull free end against remainder of wire and slip ferrule over the free end, forcing the ferrule tightly against the eye. (Of course, if a turnbuckle is to be used with the wire, the eye of the turnbuckle should be slipped on before this operation.

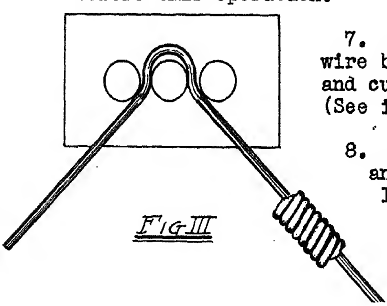


Fig. III

7. Bend free end of wire back against ferrule and cut off about 1/2" from the bend. (See illustration in "Wire and Cables").

8. Heat terminal with soldering iron and run solder into all crevices. If a ladle is available, a quicker job may be done by melting solder in the ladle and dipping the whole terminal. Never use a torch on the wire itself.

HOW TO MAKE A WRAPPED TERMINAL

Non-flexible or 1 x 19 cable cannot be spliced, and although flexible cable must be spliced when used for air controls, if the diameter is more than 1/16, there are some places, such as brake or water rudder controls, where the wrapped type of eye may be used.

MATERIALS: A piece of cable, of suitable length, a thimble of the proper size, 20 ga. soft steel tinned wire, solder, soldering flux, which should be stearic acid or a mixture of stearic acid and rosin.

TOOLS: Splicing clamp, vise, pliers, soldering iron, blow torch, (unless soldering iron is electrically heated) cable cutters.

PROCEDURE:

1. Grip splicing clamp in vise.

2. If cable has not been cut, run solder into it for a length of about 1/2" and cut in the center of the soldered portion, otherwise, the cable will unlay when cut. The cut should be made diagonally. See Fig. I. Instead of soldering, the cable may be served or wrapped tightly with the soft steel wire on each side of the point where the cut is to be made.

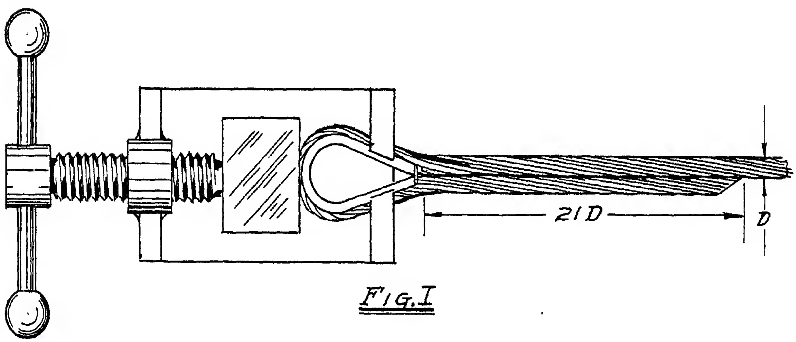


FIG. I

3. Turn up the points of the thimble, lay the cable around it and clamp in the splicing clamp, leaving a free end several inches long. The length of the free end after the job is finished should be 21 times the diameter of the cable. See Fig. I. If possible, the cable should be laid around the thimble holding this dimension, so as to avoid making another cut. It should then appear as in Fig. I. It is possible to do the job without a splicing clamp, but not as handily.

HOW TO MAKE A WRAPPED TERMINAL
(continued)

4. Insert end of soft steel wire between the two cables under the turned up points of the thimble and begin wrapping the wire around the two parts of the cable, drawing each turn tight and close against the preceding turn.

5. After laying the turns close for a distance little less than 7D, a space equal to the diameter of the cable but not less than 1/8" should be left for inspection. Then wrap closely again. See Fig. II, which shows how the eye should appear when the wrapping is complete.

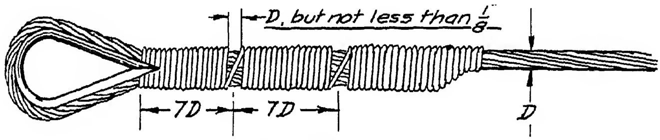


Fig. II

6. Fill all crevices, including the inspection holes and the space between the thimble and the cable with solder until flush with outside of wrapping. Wipe off excess solder while hot. This completes the job.

Note: Instead of using a soldering iron the whole terminal may be dipped in melted solder if a melting ladle is available.

HOW TO MAKE A FIVE-TUCK NAVY SPLICE

This is one of the only two splices approved by the Civil Air Regulations for use on control cables over 1/16" in diameter. It may be used on 7 x 7 flexible or 7 x 19 extra-flexible cable. A number of practice splices should be made before doing any of this work on an airplane which is to be flown.

MATERIALS: A piece of cable of suitable length, a thimble to fit same, a length of linen cord, a small quantity of shellac.

TOOLS: Splicing clamp, marlinespike, serving-maul if desired, pliers, cable cutters, hardwood block, a small mallet made of wood, rawhide, fiber, brass, or copper.

PROCEDURE:

1. If cable has not been soldered at the end, solder it thoroughly for a distance of about half an inch and cut in the center of the soldered portion. This is absolutely essential in cable which is not preformed, and makes the job easier in any case. This is the only soldering permitted, and as this section is ultimately cut off, the finished splice has no solder in any part of it.

2. Turn back points of thimble, lay cable around thimble, leaving a free end six to eight inches long, and clamp in splicing clamp, which may be held in a vise or not, as desired. To simplify the instructions, assume the cable clamped in such a manner that the free end is to the right and the screw end of the splicing clamp away from the splicer. Thus in Fig. I the splicer would be toward the bottom of the page.

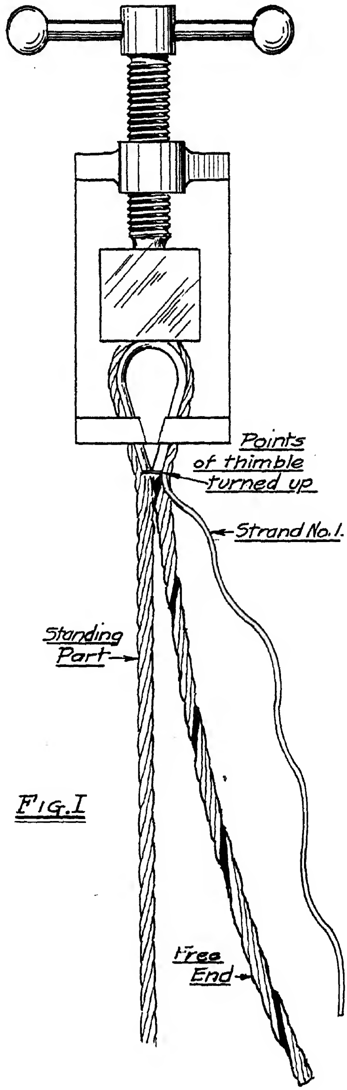
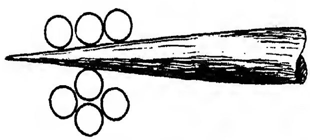


FIG. I

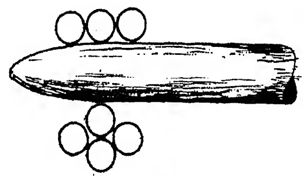
HOW TO MAKE A FIVE-TUCK NAVY SPLICE
(continued)

3. Select the strand nearest the thimble point on the free end and work the marline-spike under it gently, taking care not to catch any of the fine wires in the other strands. By rotating the marline-spike in a counter-clockwise direction around the free end, this strand will be unlaid without disturbing the remainder of the cable, which will be held by the solder at the cut. Break this first strand loose at the end. It will be referred to as No. 1. The terminal will now appear as in Fig. I.

4. Work the marline-spike under the three top strands nearest the point of the thimble on the standing part of the cable, keeping it above the core, and then turn the spike so as to lift these three strands. An enlarged view of a cross-section of the cable during this operation is shown in Fig. II.



Marline-spike inserted



Marline-spike turned

Fig. II

5. Push the end of strand No. 1 through the opening made by the marline-spike, and pull snug with pliers.

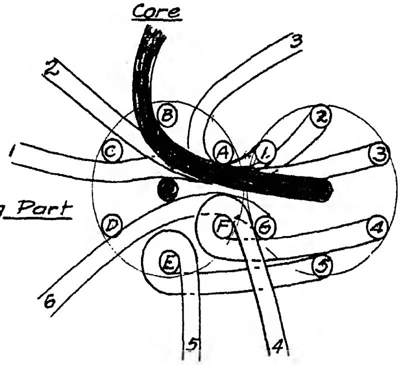


Fig. III

HOW TO MAKE A FIVE-TUCK NAVY SPLICE (continued)

6. Remove marline-spike and unlay strand No. 2 on free end, using the same method as with No. I. This procedure will be followed with each strand as it is needed, so will not be described again. An enlarged cross-section, looking toward the thimble, with the strands shown widely separated to simplify the explanation, is illustrated in Fig. III. The core strand is shown black.

7. Lift strands A and B and insert No. 2.

8. Unlay strand No. 3.

9. Lift strand A and insert No. 3.

10. Unlay core strand.

11. Lift A and B and insert core strand, drawing snug. Lay core strand along standing part and tie down with a piece of cord.

12. Unlay strand No. 6.

13. Insert marline-spike between A and F and lift F and E. Insert No. 6 in opening.

14. Unlay No. 5, lift strand E, insert 5 between E and D and bring out between E and F.

15. Lift F, insert 4 and bring 4 out between F and A.

16. Pull all strands tight with pliers, pulling toward thimble. This completes the first tuck. There should now be one strand emerging between each two of the standing part except B and C, where the core strand comes out.

17. Tuck the first strand to the left of the core strand as shown in Fig. III, over one and under one, working to the right, and passing over the core. (In this case it will be No. I, which will pass over C and under B, pulling the core of the free end to the core of the standing part.)

18. Proceed likewise with each strand in turn, as No. 2 over B and under A, No. 3 over A and under F, until all strands have been tucked. The last one will emerge at the same place as the core.

19. Pull all strands tight, with pliers, toward the thimble.

20. Repeat the procedure outlined in 17 and 18. This time No. 5 will be the first to the left of the core and the first to be tucked.

21. Pull all strands tight and cut off core strand.

HOW TO MAKE A FIVE-TUCK NAVY SPLICE
(continued)

22. Separate each strand into halves, and repeat procedure in 17 and 18 with half of each strand, beginning at any point this time.

Pull tight and cut off the half strands which were not tucked.

24. Proceed as in 22. (The strands will now be only quarter-strands).

25. Pull tight and cut off all strands as close as possible.

26. Pound the splice with the mallet, rolling it on the block of hardwood while pounding, so as to smooth out any irregularities.

27. Flatten thimble points.

28. Begin serving with linen cord half way between second and third tucks carrying the wrapping over the loose end of the cord.

29. Carry the wrapping down to a point 1/4" beyond the last tuck making the last four or five wraps around a pencil or similar object, so that they will be loose enough to push the end of the cord back under them.
See Fig. IV.

30. Pull tight, cut off cord and give two coats of shellac, allowing at least two hours between coats. This completes the splice.

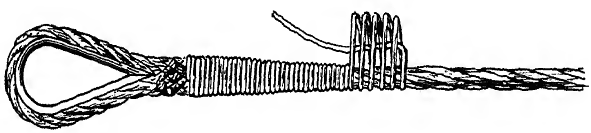


FIG. IV

HOW TO MAKE A ROEBLING ROLL SPLICE

This is the second of the two splices approved by the Civil Aeronautics Authority for use on control cables over 1/16" in diameter. See instruction sheet on the five-tuck Navy splice. The materials, tools and procedure are the same through step 16.

17. The splice will now appear approximately as shown in the enlarged view in Fig. I. Begin with any strand, but preferably No. 1; lift the strand in the standing part which is immediately above. This will be C if No. 1 is used. (See Fig. III in Navy Splice) Roll No. 1 around C in a clockwise direction as indicated by dotted lines in Fig. 1, taking care not to kink it, and pull tight, pulling away from the thimble. The roll should be made at such an angle that the wires of the two strands are parallel. If this is done carefully, the two strands will merge into one.

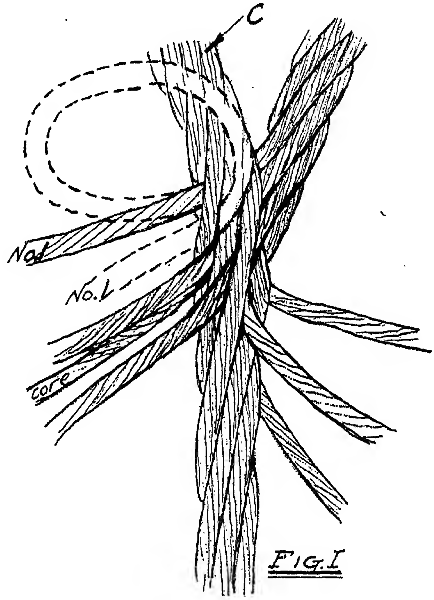


FIG. I

18. Proceed likewise with the next strand. If No. 2 is used, it should wrap around B.

19. Continue until all six strands have been rolled, leaving core strand untouched.

20. Repeat three times, making four wraps in all on each strand.

21. Lift strands B, A, and F, so that core of standing part is exposed. Wrap core of free end around core of standing part three times in a counterclockwise direction, taking care to avoid kinks. These wraps should work away from the thimble and not lie on top of the preceding wrap. See Fig. II.

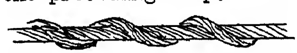


FIG. II

22. Pull tight and cut off core of free end.

23. Halve strands and repeat steps 17, 18 and 19.

24. Cut off ends, pound and serve as in Navy splice.

TIE RODS

In practically all airplanes built today, the members which carry tension only are adjustable tie rods, made from high carbon steel cadmium-plated, or stainless steel. Tie rods are made in several shapes: round , square , streamline , or full streamline , though the last is supplied on special order only and is seldom used.

The shape is produced by drawing or rolling, sometimes called swaging, a round steel rod until all but the ends has been reduced to the desired section. The ends are left round for threading, and of a greater sectional area, so that they will be as strong as the rest of the tie rod after the threads have been cut. The round and square tie rods are used for internal bracing, a short portion at each end of the round type being left square so that a wrench may be used for adjustment. The streamline type is used for external bracing. This type is supplied with a round section at any point in its length, for use where two rods cross and touch each other, as it is obvious that two sharp edges in contact would cause dangerous wear.

TIE RODS

Streamline Tie Rod assembled with Standard Rigid Terminals.

Square Drawn Tie Rod assembled with Macwhyte Safe Lock Terminals.

Round Drawn Tie Rod assembled with Standard Rigid Terminals.

Round Drawn Tie Rod, threaded only.

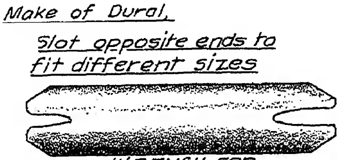
Streamline Tie Rod with Cylindrical Section.

Tie rods are made adjustable by having one end threaded with a right hand thread and the other with a left hand thread. These threads screw into terminals (sometimes called clevis ends) which are attached to the rest of the structure by clevis pins or bolts. Then when the tie rod is rotated by means of an adjustable wrench or the special tie rod wrench shown in Fig. II, it becomes tighter or less tight, depending on the direction of rotation.

The "size" of a tie rod is the diameter at the "shoulder" as shown in Fig. III, and in specified sizes, the thread is often given too, as "6 - 40" or "1/4 - 28". In ordering replacements, the size should be given and the length of the rod without terminals, or else the length between pin centers, but it should

TIE RODS
(continued)

be definitely stated which length is desired. The material should also be specified, that is, whether cadmium-plated steel or stainless steel, and also the type of terminal.



WRENCH FOR STREAMLINE TIE RODS

There are only two types of terminals in common use today, the Standard and the "Safe Lock", illustrated in Fig. IV. There is a third type called the Universal Strap Terminal which was once used, but is seldom found on modern ships. It consists of a slotted strap bent into a loop, with a cylinder of steel, or trunnion, inside the loop. The ends of the loop attach to the fitting just as any other terminal. The trunnion is drilled diametrically and threaded to fit the tie rod, which passes through the slot. Theoretically, this provides a universal joint to eliminate any bending of the tie rod and absorb vibration, but practically, the friction between the trunnion and the loop, especially if either is rusty, is so great that the purpose is defeated.

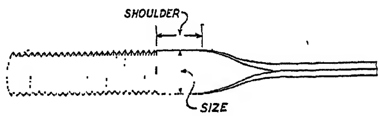


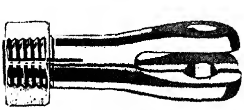
FIG. III

INSTALLATION AND INSPECTION

Tie rods are ordinarily installed, when in a vertical plane, with the right hand thread to the bottom, and when in a horizontal plane, with the right hand thread to the front, though the second rule is not followed as consistently as the first. The reason for having a definite location for the right hand thread is that there is no doubt then on the part of the mechanic as to which way the lock nut or the tie rod should be turned.

Right and Left Hand

STANDARD RIGID TERMINAL



Right and Left Hand

MACWHYTE SAFE LOCK TERMINAL

Before screwing the rod into the terminal, the threads should be covered with light grease. Tighten the tie rod with a wrench at each end, as close to the shoulder as possible. If an adjustable wrench is used, it should fit accurately. The proper degree of tension or tightness can be learned only by experience. However, if the tie rod vibrates in flight, it is usually desirable to tighten it half a turn at a time until it no longer vibrates, though sometimes, if it is very tight to start with, vibration may be stopped

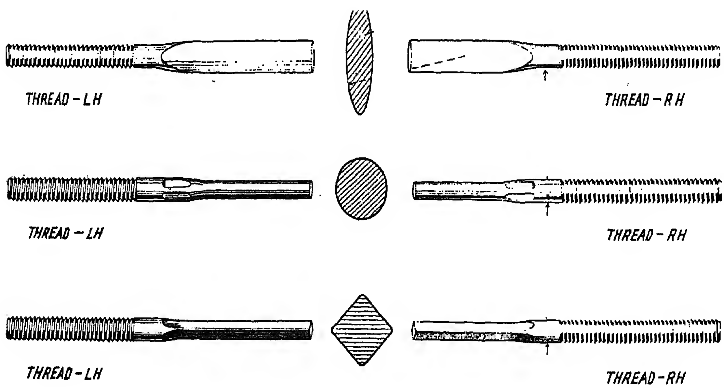
TIE RODS
(continued)

by loosening it slightly. Where square tie rods cross and touch each other they should be turned so that the flat surfaces are in contact. Streamline tie rods should never be installed so that they touch each other unless there is a round section left at the point of contact. When any of the types touch each other or any other material, they should be protected with a small piece of sheet fiber held in place with copper or brass wire. If no fiber is available, a piece of friction tape may be folded into a small pad and used instead.

When the wires have been properly tightened, the ends should be locked. This is also, to some extent, a matter of experience. In general, however, in the case of the standard terminal, the lock nut should be tightened one-sixth of a turn after it comes in contact with the terminal. Tightening the lock nut too much in this type puts undue strain on the rod. This was responsible for the development of the "Safe Lock" terminal in which the lock nut squeezes the slotted end of the terminal around the tie rod. The danger in this type is the possibility of stripping the thread if too much force is used in tightening.

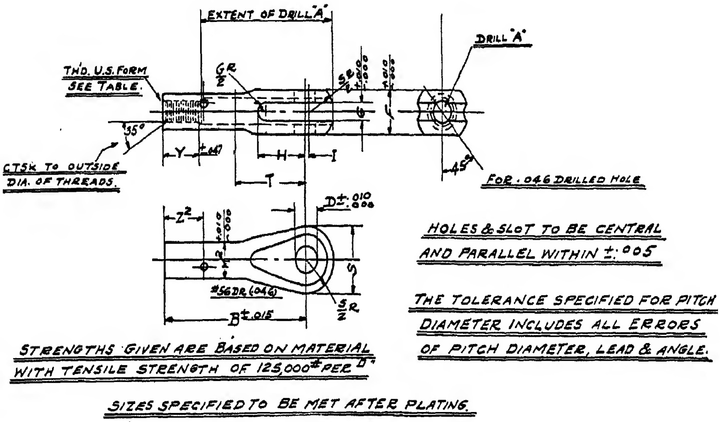
If the threaded end of the tie rod is not screwed far enough into the terminal, it may strip the threads and pull apart. In order to determine whether or not it is safe, an inspection hole is provided in the standard terminal and a slot in the safe lock. To check the safety of the standard terminal, push an ordinary dressmaker's pin into the inspection hole, which is located about twice the diameter of the tie rod from the threaded end of the terminal. In the case of the safe lock, push the pin in at the bottom of the slot in the threaded end. If the pin goes in, the connection is NOT safe, and a longer tie rod will have to be used.

SIZE AND TH'DS.	6-40	10-32	1/4-28	5/16-24	3/8-24	7/16-20	1/2-20
STRENGTH- LBS.	1000	2100	3400	6100	8000	11,500	15,500

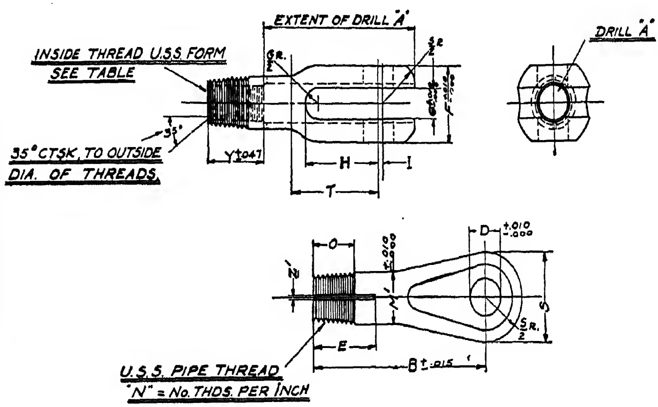


TIE RODS
(continued)

Dimensions of Standard Rigid Terminals



Dimensions of Macwhyte Safe Lock Terminals



TIE RODS
(continued)

DIMENSIONS OF STANDARD AND SAFELOCK TERMINALS

STRENGTHS GIVEN ARE BASED ON MATERIAL WITH TENSILE STRENGTH OF 125,000# PER □"

SIZES SPECIFIED TO BE MET AFTER PLATING.

THE TOLERANCE SPECIFIED FOR PITCH DIAMETER, INCLUDES ALL ERRORS OF PITCH DIAMETER, LEAD AND ANGLE. M' AND Z' REFER TO SAFE LOCK, M^2 AND Z^2 TO STANDARD

DIMENSION TABLE

HAND	WIRE STGTH	INSIDE THREAD	PITCH DIAMETER	DRILL SIZE	DRILL "A"	B	D	E	F	G	H	I	M^1	THDS. PER IN. N	O	S	T	Y	Z^1	L	C	M^2	Z^2
L.H. / R.H.	1000	6-40	.1218 +.0017 .000	#33 .1130	.147	1.313	.188	.313	.250	.109	.375	.031	.293	40	.375	.375	.625	.250 1/4	.031	1/4"	3/8"	.250	.313
L.H. / R.H.	2100	10-32	.1697 +.0019 -.000	#21 .1590	.199	1.532	.188	.375	.313	.150	.469	.031	.335	32	.375	.500	.719	.313 5/16	.031	5/16	7/16	.281	.375
L.H. / R.H.	3400	1/4-28	.2268 +.0022 -.000	#3 .2130	.261	1.813	.250	.500	.438	.203	.625	.047	.439	27	.500	.625	.875	.438 7/16	.031	15/32"	9/16"	.375	.500
L.H. / R.H.	4600	5/16-24	.2854 +.0024 -.000	.2703	.323	1.875	.313	.625	.500	.203	.656	.047	.502	27	.500	.688	.938	.563 9/16	.031	7/16	5/8	.438	.625
L.H. / R.H.	6100	5/16-24	.2[illegible]54 +.0024 -.000	.2703	.323	2.000	.375	.625	.563	.203	.843	.063	.502	18	.624	.750	1.000	.563 9/16	.062	15/32"	3/4"	.453	.625
L.H. / R.H.	8000	3/8-24	.3479 +.0024 -.000	Q .3320	.386	2.250	.375	.750	.563	.266	.875	.063	.643	18	.624	.875	1.125	.688 11/16	.062	15/32"	3/4"	.547	.750
L.H. / R.H.	11,500	7/16-20	.4050 +.0026 -.000	W .3860	.453	2.500	.438	.813	.719	.344	1.000	.078	.734	18	.687	1.063	1.250	.750 3/4	.062	5/8	15/16	.625	.813
L.H. / R.H.	15,500	1/2-20	.4675 +.0026 -.000	.4492	.516	2.813	.500	.938	.813	.406	1.188	.078	.799	18	.687	1.188	1.438	.875 7/8	.062	5/8	15/16	.703	.938
L.H. / R.H.	20,200	9/16-18	.5264 +.0030 -.000	.5062	.578	3.125	.563	1.063	.922	.453	1.375	.094	.892	18	.750	1.375	1.625	1.000	.062	11/16	1 11/16	.796	1.063
L.H. / R.H.	24,700	5/8-18	.5889 +.0030 -.000	.5687	.640	3.375	.625	1.188	1.032	.516	1.500	.094	.971	18	.750	1.500	1.750	1.125	.062	11/16	1 1/8	.875	1.187

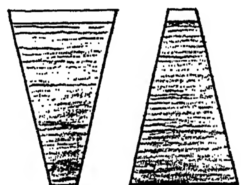
Tie rods should be inspected regularly for corrosion, especially in the case of seaplanes. Stainless steel is the proper material for tie rods used around water. If the ship is equipped with the cadmium-plated type, it is highly desirable to paint them with a good oil base primer followed by two coats of aluminum enamel, though a color scheme to match the rest of the ship may be used if desired. Any worn spots in the paint will show up quickly and should be cleaned and repainted immediately. Stainless steel rods should be wiped down with an oily rag at frequent intervals, a practice which will keep them bright and shiny.

HYDRAULIC SYSTEMS

PRINCIPLES OF HYDRAULICS - Hydraulics is the science of liquids, particularly liquids in motion. Since many of the devices on aircraft are hydraulically operated, it is highly important that the mechanic thoroughly understand these principles. The operation of such units as oleo landing gears, hydraulic brakes, landing gear retracting mechanisms, flap controls, etc., will then be much more readily grasped.

One of the first points to bear in mind is the fact that liquids are practically incompressible, and that therefore their volume does not change appreciably under pressure. The second point is that pressure on any portion of a body of liquid or of two or more connected bodies is transmitted uniformly throughout the entire quantity. Thus, if we have a closed container, containing, for example, a pint of liquid and connected by a pipe to another closed container containing a gallon of liquid, a pressure of ten pounds per square inch on the liquid in the pint container will produce the same pressure over the entire inside of the gallon container.

Another and very peculiar fact is that the pressure on a given level of liquid is the same, regardless of the shape of the container. In the three containers shown in Fig. I, the level of the liquid is the same. Assume that the areas of the bottoms of (a) and (b) are each one square inch and that of (c) is 25 square inches. Then the pressure in pounds <u>per square inch</u> is the same on the bottoms of <u>all</u> three, but the <u>total</u> pressure in pounds is 25 times as much on (c) as it is on each of the others. Thus, if the height of the liquid were such as to produce a pressure of 2 lbs. per sq. inch on the bottom of (a), then the total pressure on the bottom of (a) would be just 2 lbs.(since the area of the bottom is 1 sq.in.); the total on the bottom of (b) would also be 2 lbs; but the total pressure on the bottom of (c) would be 2 x 25, or 50 lbs. This might be much more than the actual weight of the liquid in (c); nevertheless the pressure is there just the same and will push the bottom of the vessel out unless it is strong enough. This peculiar fact is known as the <u>hydrostatic paradox</u>.



(b) (C)

FIG. I

The fact that pressure is transmitted uniformly through connected bodies of liquid is used in the design of many hydraulic mechanisms, one of the simplest of which is the hydraulic jack. The principle is illustrated in Fig. II.

Assume that the area of the pump piston is one square inch and that of the jack piston ten square inches. If the operator exerts a force of 50 lbs. on the handle, the force on the pump piston will be (50 x 30) / 6 = 250 lbs. (See "Moments" page 351). Since the area of the pump piston is one square inch, the pressure on the liquid in the pump, and, hence, in the cylinder of the jack, is 250 lbs. per sq. in. The area of the jack piston is ten square inches. Then the

HYDRAULIC SYSTEMS
(continued)

total force on the jack piston is 250 x 10 = 2500 lbs. Thus the operator, by exerting an effort of only 50 lbs., produces a force of

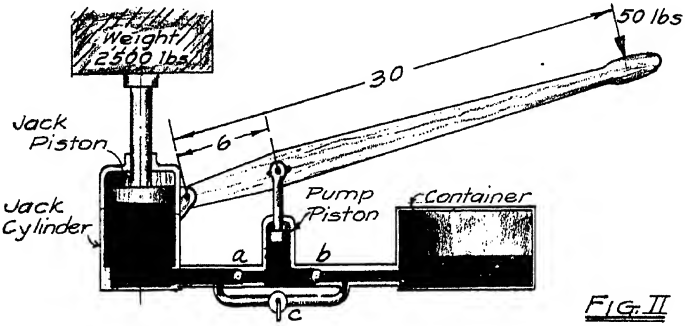


FIG. II

2500 lbs. There is no pressure on the container since the ball check valve at "b" prevents the liquid from flowing from the pump to the container. The check valve at "a" prevents the liquid from flowing back from the cylinder to the pump while the pump is making a fresh stroke. To lower the jack a shut-off cock "c" in the by-pass line is opened, allowing the liquid to flow from the cylinder into the container. Many adaptations of this design are used, but the basic principle is the same in all.

HYDRAULIC MECHANISMS

In large airplanes, the various hydraulic mechanisms are usually all connected to each other. Instead of a hand pump, an oil pump, usually of the gear or fixed vane type, is driven by the engine and supplies oil for their operation. Oil is used instead of water because it does not freeze or evaporate, and, furthermore, lubricates the working parts. The oil itself is of a special type which does not thicken in cold weather. The flow to the individual mechanisms is controlled by suitable shut-off cocks. The pumps are usually capable of producing a pressure of about 2000 lbs. per sq. inch. Since the pump is working whenever the engine is running, pressure relief and by-pass valves must be provided. The pressure relief valve maintains the desired pressure and the by-pass permits the oil to pass back into the storage or oil-reserve tank.

In many modern transport planes, the landing gear hoist, the flap mechanism, the Sperry automatic pilot, and the wheel brakes are all connected into the same system, which is quite complicated, and requires considerable study to understand. Since systems vary with different types of planes, it is impossible to illustrate them here. A diagram of a simple system which includes the general principles is shown in Fig. III. It should be noted that the pressure applied by this system to the brakes is controlled by suitable valves connected to the brake pedals in the cockpit. This arrangement makes it unnecessary for the pilot to use much effort in operating the brakes. Without something of the kind, difficulty would be experienced in properly braking a ship weighing 20,000 lbs. or more.

HYDRAULIC SYSTEMS
(continued)

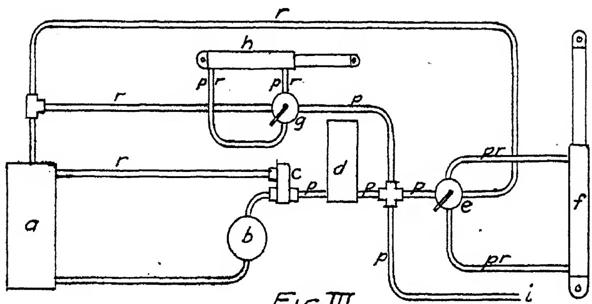


FIG. III

a - Storage or reserve tank
b - Engine pump
c - Pressure relief and by-pass valve
d - Pressure cylinder
e - Selector valve for landing gear hoist strut
f - Landing gear hoisting strut
g - Selector valve for flap operating strut
h - Flap operating strut
i - Line to other mechanisms
p - Pressure lines
r - Return lines
pr - Alternate pressure and return

The oil for the system is stored in the reserve tank, (a), from which lines run to a pump on each engine. One of these is indicated at (b). A pressure relief and by-pass valve, (c), must be installed for the pump is capable of delivering much more oil than the system can use. This valve is set for the proper pressure. When this pressure is reached, the excess oil returns to the tank. This is, of course, also the case when the system is not in use, since the pump is operating whenever the engine is running.

The pressure cylinder (d) contains compressed air at the top and oil at the bottom. It serves the double purpose of making the oil pressure uniform at all times and of maintaining a pressure on the system when the engine is idling or stopped entirely. The selector valves (e) and (g) determine the flow of oil to their respective units. Turning the valve to one side causes the oil to flow to one side of the piston in the hoist and permits the oil on the other side to return to the tank. Thus the line marked (pr) may be either pressure or return lines. If the valve is turned to the other side, the oil flow is reversed. An intermediate position of the valve cuts the unit off entirely.

HYDRAULIC SHOCK ABSORBERS
The fact that liquids are practically incompressible is also used in shock absorbers, or "oleo struts", for landing gears. The application of the principle, however, is different from that just discussed. In the shock absorber, the load applied to the strut

HYDRAULIC SYSTEMS
(continued)

when the wheels come in contact with the ground forces liquid through a small orifice or hole. In this manner the energy is completely dissipated without storing up more energy, and there is no rebound or bounce. Such is not the case when the shock is taken by compressed air, a spring, or rubber in compression or tension. The energy is absorbed by these mediums, but is stored up. If the plane is landed smoothly and perfectly so that its weight is applied gradually without excess load, the spring, rubber, or pneumatic shock absorber is not deflected beyond normal. ("Normal" deflection occurs when the ship is at rest on the ground.) Hence, there is no recoil or "bounce." On the other hand, if the field is rough, or if the pilot "drops" the ship, (a "pancake" landing), the deflection may be several times the normal. The energy thus put into the shock absorber must come out again, and in so doing throws the plane back into the air.

The basic principle of the hydraulic shock absorber may readily be understood by referring to Fig. IV. Two cylinders or tubes are arranged so that one telescopes into the other. The inner or smaller tube is closed at its inside end by a plug or piston which has a small hole through it, as at (h). The outer or larger tube is filled with oil. When a load is applied in the direction of the arrows in Fig. IV (a), the oil is forced through the hole (h) and the strut collapses or deflects to the condition shown in (b). The energy of a shock is thus used up in forcing the oil through the hole and there is no tendency for the strut to return to the extended condition (a). Hence, there is no recoil or bounce.

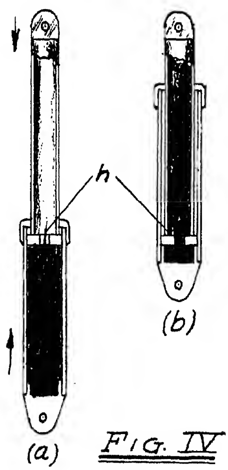


FIG. IV

Many modifications of this general idea are employed. Resilience for taxiing may be provided by a short coil spring at the bottom of the large tube or by compressed air. In such cases, however, the initial shock is taken on the oil as just described. In some shock absorbers a long, tapered rod is attached to the bottom of the outer tube, the small end of the taper passing through the hole in the lower end of the inner tube. Due to the taper of the rod, a relatively large opening is allowed at the beginning of the stroke. As the tubes telescope, the opening between the rod and the hole becomes smaller and smaller, so that more and more energy is required to collapse the strut.

Several types of hydraulic or "oleo" shock absorbers are discussed later.

LANDING GEARS

The landing gear is the understructure of an airplane which supports the weight of the airplane when it is on the ground or water. It is usually equipped with a device to reduce the shock of landing and taxying. There are three types of landing gears; wheels, skis, and floats. The latter are discussed under "Hulls and Floats".

The conventional type of landing gear for airplanes consists of two main supporting wheels ahead of the center of gravity and a trailing tail support called either a tail skid, or a tail wheel, as the case may be. This provides a three point support, from which has come the term "a three point landing". This means a landing in which all three supporting points touch the ground at the same time.

Landing gears are designed to permit a three point landing to be made when the airplane is in its landing attitude, that is, when the airplane is at its stalling angle with the power off. In addition to supporting the airplane at the correct angle, the landing gear must be so placed and high enough to provide the propeller with a ground clearance of at least 9" when the airplane is in flying position. This is to prevent the propeller striking small objects on the ground when taking off.

Landing gears have to be so designed and built that they will stand the strain of hard landings, cross wind landings and the general abuse that they may receive from fast taxiing, ground looping, etc. For this reason the landing gear struts are usually made of heat treated steel tubing. The axle struts must be heat treated as required by the Civil Aeronautics Authority. The struts are always connected to some major station point usually in the fuselage. This is essential in order to distribute the landing shock over as large an area as possible. If the struts are attached to a station point outside of the fuselage, either on the wing or on brace struts, the landing shock is transmitted directly from any such station into the fuselage.

CANTILEVER LANDING GEARS

Cantilever landing gears are those gears that are internally supported or braced in such a manner that a single strut with no external bracing struts or wires, can be used. This type of is becoming quite popular, as it reduces the drag considerably when the external bracing is eliminated.

Fig. I shows the installation of the shock units in the cantilever landing gear used on the "Stinson Reliant".

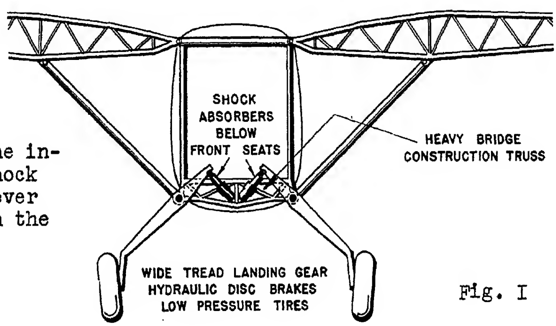


Fig. I

LANDING GEARS
(continued)

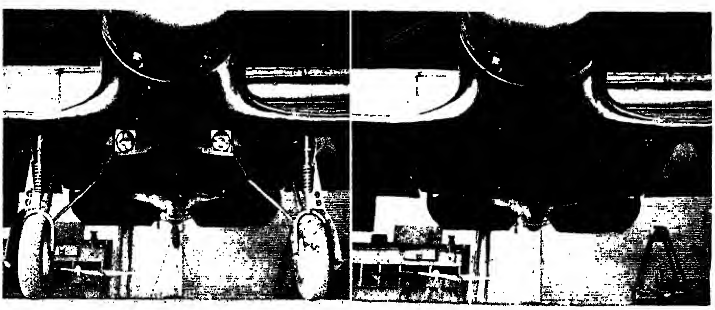
RETRACTABLE LANDING GEARS

Fig. II

Retractable landing gears are those that may be raised or lowered while in flight, and in the case of an amphibian, when the plane is on the water. Retractable gears are used on an amphibian to permit the wheels to be raised when making a water landing or take off, and lowered for a land take off or landing. Retractable landing gears are used on land planes to raise the wheels into the fuselage or wings to reduce the air resistance or drag. Many amphibians are now retracting the gear into the hull or wing to reduce drag.

There have been no successful attempts made to standardize retractable gear mechanism, and almost every airplane that has a retractable gear uses a system of its own. Some gears are operated by hand with a pump, crank, or lever, and some by foot. Some operating mechanisms are strictly mechanical, and others are pneumatic, electrical, or a combination of both.

No specific directions can be given as to the maintenance of retractable gears, due to the great variety of types and systems. However, in general, the gear should be inspected periodically and kept free and clean. All moving parts should be kept well lubricated. In the case of an amphibian, the gear should be washed with fresh water after every water flight.



Retractable Landing Gear on a Beechcraft
Fig. III

LANDING GEARS
(continued)

SKIS

Airplanes may be equipped with skis for landing in snow. They are so designed that they may be attached directly on the wheel axle, thus taking advantage of the standard shock absorber. Fig. IV shows an airplane equipped with skis. The heavy cord from the front of each ski to the fuselage is a rubber shock cord under tension. This pulls the front end of the ski up as the tail is raised, so that the airplane will not "trip" over its skis. A flexible wire is connected from the rear end of each ski to the fuselage to prevent the shock cord from pulling the front end of the ski too high after the ship is in the air. Note: A safety wire of flexible cable should be installed to prevent the ski folding under, in case the shock cord breaks.

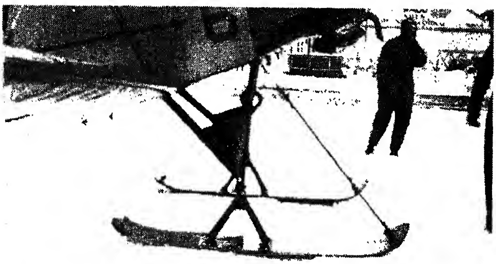


Fig. IV

Fig. V shows a set of skis. The tail ski is not used except where the snow is deep; ordinarily the conventional tail skid is used. Notice the "snow brakes" installed immediately in front of the ski supports.

TAIL SKIDS AND WHEELS

Practically all of the early airplanes were equipped with a tail skid. The tail skid serves two purposes; to support the tail of the airplane and to act as a drag brake after landing. The tail skid shoe, or that part of the assembly in contact with the ground, is subjected to considerable wear, especially if landings are made on hard surfaced runways. For this reason they are usually protected against wear by welding a coating of stellite on the bottom of the shoe.

Tail skids are not entirely satisfactory as they put quite a strain on the fuselage, especially if the pilot makes a tail low landing, that is, if the tail skid strikes the ground slightly before the wheels touch. On hard surfaced runways, tail skids are ob-

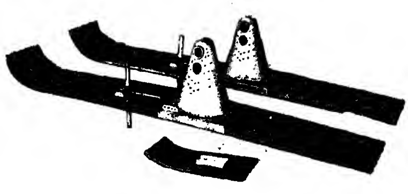
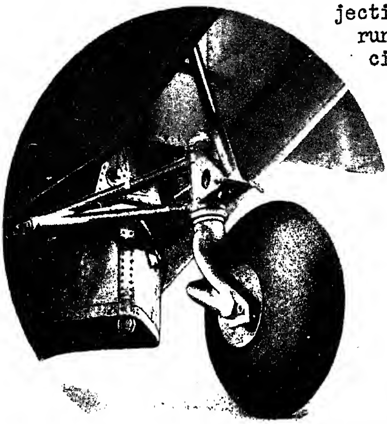


Fig. V

LANDING GEARS
(continued)



Sikorsky Tail Wheel

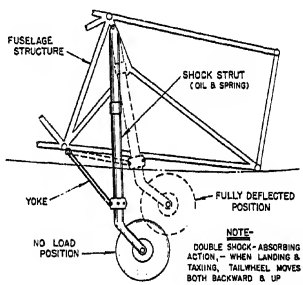
jectionable as they either tear up the runway or they do not provide sufficient braking power.

Where the conventional brakes are used to provide the braking power, a tail wheel can be used. There are many types of tail wheels, ranging from a hard rubber roller to a low pressure pneumatic tire. The tail wheel affords a much safer landing than does the tail skid, with less strain to the fuselage.

To assist in steering, some tail wheels are installed so that they turn with the rudder. These are called steerable tail wheels. They are connected by control wire to the rudder pedals in the cockpit.

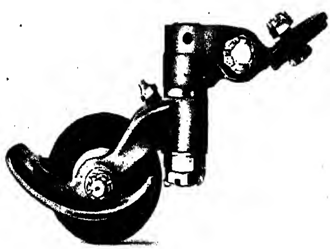
There is usually a heavy coil spring mounted in each control cable line so that in case the tail wheel becomes jammed, the pilot will still have full control of the rudder.

Most tail wheels that are not steerable are at least installed so that they are free to swivel through 360°. A swivel tail wheel greatly adds to the ease of the ground handling of an airplane.



Stinson Tail Wheel

Streamline Tail Wheel



Hard Rubber Tail Wheel

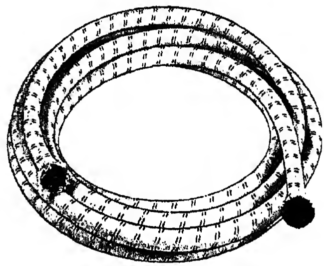
SHOCK ABSORBERS

There are many types of devices used on landing gears to reduce the shock transmitted to the fuselage in landing and taxying. These are called the shock absorbing units and are present, in some form, on all landing gears except those designed for water landings. The various types of shock absorbers in use today may be divided roughly into the following classes: Shock cord and shock rings; coil and leaf springs; rubber compression discs and washers; oil or hydraulic; and low pressure tires.

SHOCK CORD AND RINGS

Shock cord consists of a rope of rubber strands tightly encased in a woven fabric cover, Fig. I. The cover is tightly woven to protect the rubber strands from the detrimental effect of gasoline and oil. The fabric cover is woven in such a manner that when any tension is put on the cord the weave opens up, thus all the load is carried by the rubber strands. Shock cord is supplied in standard diameters from 3/16" to 5/8".

Shock Cord



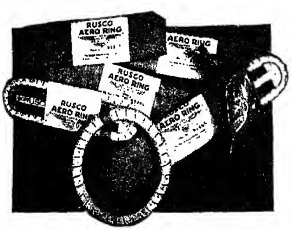
Note: Date thread.

Fig. I

A shock ring is a continuous ring of shock cord, as shown in Fig. II. It has the same fabric cover and serves the same purpose as does shock cord. The advantages of the shock rings are that they are easily and quickly replaced, and do not have to be secured by stretching and whipping.

A typical shock cord installation is shown in Fig. III. The two telescoping struts are held together by the shock cord. The landing shock extends the telescope struts, stretching the shock cord. This provides the landing gear with a certain amount of give or flexibility so that the shock is not transmitted through rigid members directly to the fuselage. It will be noticed that the shock cord is secured by whipping an eye terminal in each end of the cord.

Shock cord should be replaced as soon as it loses its elasticity to the point where it allows the shock unit to stretch or spread too far or too easily under landing shocks. This condition may be brought about by the deterioration of the rubber strands due to gasoline, oil or grease, by hard usage, or by age.



Shock Rings Fig. II

To guard against the use of old shock cord, the manufacturers have woven a colored strand in the fabric cover to serve as a code indication of the date of manufacture. A different color strand is used

SHOCK ABSORBERS
(continued)

for each year. A single, color strand is used on all cord made in the first six months of that year and two strands of the same color are used for the second six month period. The current code should be learned from the dealer before shock cord is purchased. Shock cord that is over one year old should not be used.

Shock Cord Installation Fig. III

Before the original shock cord is removed, the direction and number of turns should be noted, also the position of the terminals, so that it may be replaced correctly. The replacement is usually started with an eye terminal such as is shown in Fig. IV. The cord should be stretched while the terminal is being whipped, or served. Rib stitching cord or some suitable substitute should be used for serving. Each turn should be a half hitch and if time permits, the finished serving should be given one or two coats of clear dope. The cord should be stretched at least 10% as it is being wrapped and the second end secured with a whipped eye terminal. If shock rings can be used as a replacement it is recommended, as all the stretching and whipping is eliminated.

COIL AND LEAF SPRINGS

Coil springs are used considerably for the shock unit in tail support assemblies. They are rarely, if ever, used as the sole shock absorbing device. This is due mainly to its weight. A coil spring of sufficient size to handle the landing shock properly, would be much heavier than the conventional units.

Leaf springs are limited to tail skid assemblies on many of the small commercial biplanes, although in one or two cases they have been used in the main gear. Both the coil and the leaf spring have the advantage of requiring no adjustments and only a slight amount of attention.

The most important items in spring shock absorber maintenance, are to keep the springs clean and free from any accumulations of dirt, sand, etc. and to keep the springs properly greased to insure smooth action and to prevent rust. This is doubly essential on spring installations on amphibians.

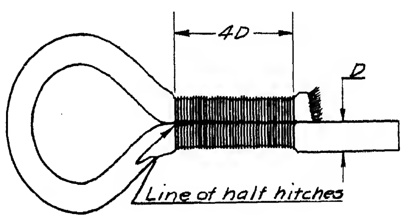


FIG. IV

SHOCK ABSORBERS
(continued)

RUBBER COMPRESSION DISCS OR WASHERS

Fig. V shows a typical landing gear using rubber discs in the shock absorbing unit, the shock of the landing being absorbed by the compressing of the semi-hard rubber discs. Units of this type were, at one time, very popular but like shock cord units they are being replaced by hydraulic shock absorbers. Their greatest use today is in tail support assemblies.

Rubber compression disc units should be protected from all oil, gasoline, etc., with a dural streamline. The streamline should be easily removable so that frequent inspection can be made. The discs should be replaced as soon as they lose their shock absorbing qualities.

Fig. V

HYDRAULIC SHOCK STRUTS

Almost all airplanes at present use some form of a hydraulic shock absorbing unit. There are many types of hydraulic struts used, but in general they can be divided into two classes; the pure hydraulic and the compressed air hydraulic. A typical installation of a hydraulic strut is shown in Fig. VI. A somewhat similar installation is shown in Fig. VII.

Typical hydraulic and compressed air hydraulic struts are shown in Figs. VIII and IX. Note: These illustrations and the following description and instructions are furnished by the courtesy of the Cleveland Pneumatic Tool Co., manufacturers of Aerol struts.

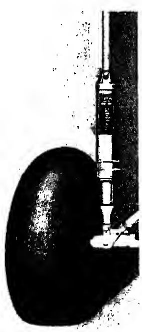


Fig. VI

INSTRUCTIONS. STRUT, FIG. 8

"Aerol Struts should be filled with oil occasionally. Fill Struts with plane at rest on level ground with no load. Remove plug (No. 14) and fill with Aerol Strut Oil.

"If there is any indication of oil leakage by the packing, loosen lock nut (No. 12) and tighten Follower Nut (No. 4), then tighten the Lock Nut.

Fig. VII

SHOCK ABSORBERS
(continued)

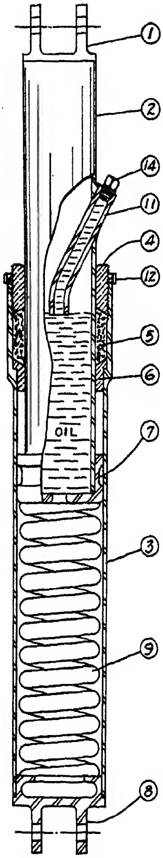


Fig. VIII

AEROL OLEO-SPRING STRUT (8)
1 Upper Terminal
2 Piston Tube
3 Cylinder
4 Follower Nut
5 Packing
6 Follower
7 Piston Head
8 Lower Terminal
9 Steel Spring
11 Oil Filler Tube
12 Lock Nut
14 Filler Tube Plug

AEROL OLEO-PNEUMATIC STRUT (9)
1 Upper Cylinder
2 Piston Tube Assembly
3 Upper Packing Follower
4 Special Gland Packing
5 Gland Lock Nut
6 Packing Gland Nut
7 Felt Wiper Ring
8 Air Valve Body
9 Air Valve Dust Cap
10 Air Valve Inside
11 Primer Plug
12 Valve Cap

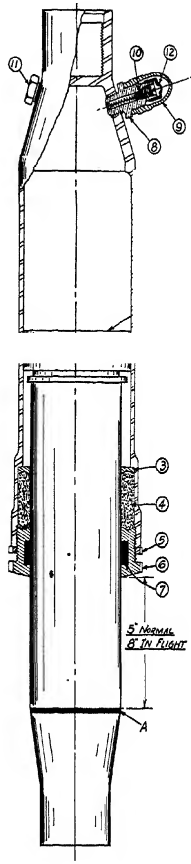


Fig. IX

"INFLATION INSTRUCTIONS - Fig. IX
1. Remove Dust Cap (No. 9) and Valve Cap (No. 12), then attach air hose to valve body.
2. Inflate with compressed air only until red line on piston tube (A) is approximately five inches below Packing Gland (No. 6). Move airplane forward and backward several times while inflating to allow the wheels to take their normal position.
3. Check Air Valve Inside (No. 10) to be sure it does not leak. Replace if necessary. Replace Valve Cap, Dust Cap. The position of the Aerol Strut should be checked occasionally to insure equal inflation.

"REPRIMING INSTRUCTIONS - 1. Aerol Struts should only be reprimed when there is an indication of oil leakage.
2. Deflate by pressing Valve insides (No. 10) until Strut is fully compressed. Remove the Valve insides.
3. Remove Primer Plug (No. 11) and fill with Aerol Strut Oil.
4. Replace Primer Plug securely, replace Valve Insides and inflate.
5. If there is any indication of oil leakage at Gland (No. 6), loosen Lock Nut (No. 5), tighten Gland Nut slightly."

It should be noted that the entire lower tube, 3, in Fig. VIII is filled with oil at all times. The oil is not shown in this por-

SHOCK ABSORBERS
(continued)

tion so that the spring may be clearly seen. When the strut shown in Fig. IX is compressed, the oil occupies the space between the smaller tube and the larger. When the strut is extended, some of the space above the piston is occupied by oil, the remainder by compressed air. When load is applied, the oil passes through holes in the piston which lead from the upper chamber to the space between the larger and smaller tubes.

BENDIX PNEUDRAULIC STRUTS

The following discussion is quoted from the literature of the Bendix Aviation Corporation. There are a number of modifications of the type shown, which, however, illustrates the basic design.

"The Bendix Pneudraulic type shock strut is a combined pneumatic and hydraulic type strut designed to meet the requirements just outlined. The energy of the landing airplane is absorbed by the flow of oil through an orifice which varies at different points in the stroke and by the compression of the air above the oil as the oil level rises. The energy absorbed by the fluid flowing through the orifice is dissipated in the form of heat. Taxiing shocks are absorbed largely by the compression of the air as the velocity of the oil through the orifice under the taxiing stroke is not sufficiently great to absorb much energy. The use of air for taxiing permits reduction of weight due to elimination of the heavy steel spring or the necessary rubber.

"Utilization of a hydraulic element with a variable orifice permits actual dissipation of the absorbed energy at a constant rate throughout the stroke, thereby keeping the maximum resistance loads to a minimum. Dissipation of energy is especially important in that no rebound results from dissipated energy. Another particularly useful characteristic of a hydraulic orifice is that the resistance is developed only when and if needed because it is a function of the velocity of the piston through the cylinder. This in turn is a function of the initial vertical velocity of the airplane at contact with the ground. Therefore, the resistance developed is automatically large for a high velocity of contact and small for a low velocity. This results in the most comfortable landing consistent with the amount of energy involved.

"General Arrangement: Fig. X shows a typical general arrangement of a Bendix Pneudraulic shock strut. Essentially it consists of telescoping chambers with the lower one always filled with fluid and the upper one having compressed air in the top and fluid in the bottom. Between the two chambers is an annular orifice whose area at various points in the stroke is controlled by a variable section pin. The sliding joint is sealed by moulded packing rings designed specially for this work. The sealing lips of the rings are tightened only by the hydraulic pressure and therefore the pressure applied varies directly with the hydraulic pressure. Tightening down of the ring holding the packing in place can in no way affect the sealing lips of the packing.

"The Pneudraulic strut is filled with fluid when in the completely compressed position. High pressure air is then added through

SHOCK ABSORBERS
(continued)

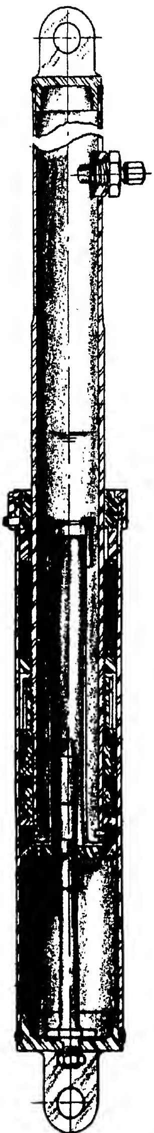


FIG. X

the air valve from an Air Bottle or by means of the Booster Hand Pump until it lifts the weight of the fully loaded airplane to the specified static position, which is usually so chosen that the wheel can travel about three inches from the static to the fully compressed position. It is unnecessary to measure the actual pressure. Unit pressures of 750# per sq. in. in the static position are permissible. Upon take-off the strut is positively extended by the air pressure. This pressure in the strut is sufficient to seal the packing against leakage.

"Action - Landing: When the tire touches the ground as the airplane lands, fluid is forced from the cylinder through the annular orifice in the piston into the upper chamber, due to the compression of the strut. The resistance to the flow of the oil through the orifice dissipates the kinetic energy of the airplane in the form of heat. As stated before, the amount of dissipation varies automatically with the impact velocity. As the fluid rises in the upper chamber, it passes freely through the flap valve on the snubber tube mounted above the orifice and compresses the air above the oil. As soon as the stroke is completed, the compressed air tends to force the oil back. This closes the flap valve and allows the oil to be metered slowly out through the small holes at the bottom of the tube, thereby preventing rebound from the compressed air in the strut. The size of these holes may be varied to suit the snubbing characteristic desired.

"Action - Taxii : As the airplane taxies across the l ng field, the velocity of the movement of the piston into the cylinder is relatively low, and the resistance to compression is furnished by the compression of the air above the oil. However, in the case of a sharp impact giving a high momentary velocity, the hydraulic dissipation would occur. The amount of air compression from the static position of the strut to the fully compressed posi-

SHOCK ABSORBERS
(continued)

tion is controlled in the design by the air space provided. Unless otherwise desired for a given installation, the design is made to give a resistance at the end of the stroke, due to air compression alone, of three times the resistance at the static position which is of course one factor. The static position is usually fixed so that the C.G. movement will be approximately three inches from static to fully compressed position of the strut. The use of compressed air permits a great deal more flexibility in design selection of taxiing stroke and resistance without appreciable change of weight than does the steel spring or the rubber ring.

"Two convenient means are available for supplying high pressure air to inflate Pneudraulic Shock Struts. One is the Bendix Booster Pump, and the other is the high pressure Air Bottle.

"The Bendix Booster Pump is a small bore, long stroke hand pump equipped with an eight foot high pressure hose. This pump is designed to take air from the ordinary service air line at from 80 to 120# pressure into the intake side and build it up to approximately 1,000# on the delivery side. If a service air line is not available, a standard automobile pump may be used to supply the intake air. The intake fitting is threaded to permit attaching the hose from the automobile pump. While it is inadvisable to attempt to furnish large quantities of compressed air in this way, these pumps are perfectly satisfactory for ordinary servicing of these struts.

"The high pressure Air Bottle is specially adapted to use where a large number of struts are to be serviced. These Bottles can be rented filled under a pressure of 2,000#/sq.in. By use of the gages and an easily controlled needle valve, it is possible to inflate struts to any desired extension."

GENERAL MAINTENANCE OF BENDIX STRUTS

"Fluid: The fluid used in the Bendix Pneudraulic shock struts, called Bendix Pneudraulic Strut Fluid, is obtainable from the Bendix Products Corporation, South Bend, Indiana. In the case of emergency, Standard Lockheed Brake Fluid No. 5 may be used for initial filling or for partial refilling. (The Bendix Strut Fluid should not be used for filling brakes.) Mineral oils must not be used, due to possibility of packing deterioration.

"Fluid Level: Whenever the installation permits, the filler plug boss is located on the centerline of the strut in the side view of the airplane in such a position that when fluid is just level with the hole in the boss, with the strut in the fully compressed position, the correct amount of fluid is indicated. Locating the hole in this position prevents possibility of error due to having the airplane in level landing as compared with three point landing position for filling. If the installation does not permit this location of the filler plug, it becomes necessary to put in an extension tube from the filler plug boss to the center of the strut of such a length that when no more fluid can be added, the correct amount is indicated. Sometimes it is necessary to locate the filler plug boss on the front of the strut or in some other position, which means that the strut must

SHOCK ABSORBERS
(continued)

always be filled in one position - usually that taken by strut when tail wheel is on the ground.

"There need be no definite inspection period for checking the fluid level in the struts. A certain amount of fluid loss, due to seepage past the packing rings, is to be expected and the fluid level in the strut will vary according to the amount of seepage, which may not be the same for any two struts. In general, however, the fluid level should be checked whenever the strut strikes bottom or top with ordinary usage when inflated to the proper extension. This indicates that the proportion of fluid to air has been decreased to a point where the air does not build up sufficient pressure to prevent bottoming. To check the fluid level, deflate the strut by depressing the valve core, then back off the filler plug one turn until all the fizzing of air and fluid stops. Remove the filler plug and check the fluid level. This level should be flush with the filler plug hole when the strut is fully compressed.

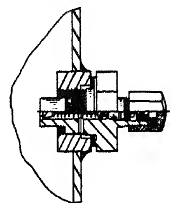


FIG. XI

"When a completely empty strut is filled, care should be taken to completely extend and compress the strut at least two times to make sure that all air pockets are eliminated before the final check for fluid level is made. This is necessary when fluid is added after the strut has been in service. If the strut is not in place on the airplane when it is filled, care must be taken to place it under same angular conditions as on the airplane when final level is checked.

"Inflation: The actual air pressure required to inflate Pneudraulic shock struts depends upon the axial load on the strut due to the weight of the airplane and also the friction due to the packing and any bending or torsional loads on the strut. These pressures vary from 200 to 800#/sq.in. Due to the small quantity of air in the strut and the relatively high pressure required, it is inadvisable to attempt to measure the pressure with a gauge. This is unnecessary as the correct pressure is indicated when the specified extension of the strut is obtained under the full load. If it is more convenient to check pressures under a light load, the actual extension under this load should be noted after the strut has been properly inflated under the full load. The correct extension under full load is specified on the Instruction Plate.

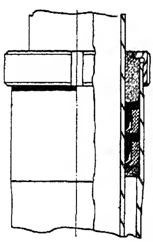


FIG. XII

"Either a Bendix Booster Pump or High Pressure Air Bottle may be used for inflating struts. For first inflation the distance should be approximately $\frac{1}{4}$" greater than specified as moving the airplane around will cause some absorption of the air by the fluid. A variation of $\frac{1}{4}$" either way for final reading should not be considered of importance.

SHOCK ABSORBERS
(continued)

Adjustment should be made with the airplane out of the wind and without the slip-stream from the propeller, and after the airplane has been moving forward, tail on the ground. The airplane should also be rocked occasionally while inflating to overcome packing friction, thus preventing inadvertent over-inflation.

"After the struts are once correctly adjusted, readjustments should not be made for minor changes, as this may be due to change in position of airplane, change of load, wind action, packing friction, rolling the airplane backward, etc. Always check only after airplane has been correctly loaded and has been rolled forward with tail down. Do not over-inflate, as hard taxiing and bounce at contact will result.

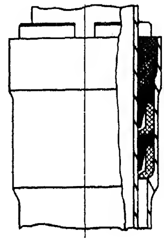


Fig. XIII

"The filler plug, which also contains the air valve, is provided with an annular ring on the under side of the hex. A soft copper gasket is provided between this ring and the plug seat on the strut. These seats must be free from dirt and marks, and the plug must be seated snugly to prevent air leaks at this point. If needed, a new gasket should be used each time the plug is replaced. (See Fig. XI.)

"Air Valves: Two types of air valves are suitable for use in these struts. Both are special types, developed for this purpose, one by Schrader's Sons and the other by Dill Mfg. Co. These valves function like the ones in an automobile tire. The hex cap provided with this type of valve has a soft metal seat to furnish a secondary seal. It should be screwed down tightly, but not so tightly that the tin seat in the cap is forced inward, thereby depressing the valve core stem. The cores are replaceable.

"The valve core and the seat around the filled plug should be tested for leaks by putting a little oil on these joints to show the presence of air bubbles. Mineral oil should not be allowed to reach the packing rings, as gumming may result.

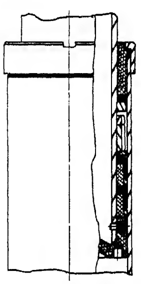


Fig. XIV

"If the air pressure is especially high, it is desirable to not over-inflate struts as experience shows the valve cores are more easily damaged by the releasing ofhigh pressure air through them than in any other way. Under the pressure ordinarily used, no difficulty results from this condition.

"Packing: The packing used in the Pneudraulic Strut is a special Aircraft Packing, designed specially for this work. Two

SHOCK ABSORBERS
(continued)

moulded composition rings separated by aluminum alloy spacer rings are used. One type of design of the packing box requires rings with inside flexible sealing lips, and the other type requires rings with the flexible lips on the outside.

"Sealing on the lip side of the packing is accomplished automatically by the hydraulic pressure; hence, any leakage on this side of the packing can not be remedied by tightening down on the packing nuts. However, leakage past the fixed side of the packing can usually be eliminated by tightening down on the packing nut as the heel of the ring is thus forced firmly against the packing gland wall. Packing rings, which will, of course, wear out in service, may be replaced as follows:

(1) Release all air from strut by depressing stem of valve core.
(2) Remove filled plug and pour out fluid.
(3) Unscrew nut at end of cylinder.
(4) Pull out piston tube assembly, if necessary, using a slight bumping action to break rings loose.
(5) Study of this assembly will show how rings may be removed.
(6) New rings should be installed in same manner as old ones.
(7) After rings are installed, tighten packing nut down firmly to provide seal at heel of ring on side opposite lip.
    (a) If the rings are of the inside lip type, the packing nut is on the cylinder and is tightened down as the last assembly operation. (See Fig. XII and Fig. XIII.)
    (b) If the rings are of the outside lip type, the packing nut is on the piston tube. It should be tightened down snugly before the piston tube assembly is inserted in the cylinder. After the piston and rings are in the cylinder, but with the packing nut still outside, the nut should be tightened down firmly. In this case the nut at the end of the cylinder is used to prevent the strut from pulling apart. (See Fig. XIV.)

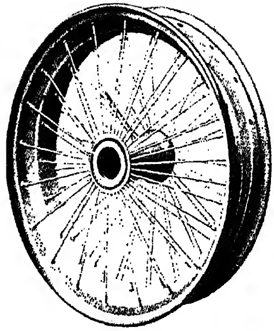
"Storage: Struts should not be kept in storage in the inflated condition, except for short periods, or when desired for immediate replacement, as the packing deteriorates as much when under air pressure in storage as in service. When struts are to be stored for long periods as spare parts, it is recommended that the inside be coated with a rust preventative, and that the struts be assembled without packing or fluid.

"It is, of course, very important that the rust preventative be thoroughly cleaned out before the strut is provided with new packing, filled and reassembled for service."

WHEELS AND BRAKES

WIRE WHEELS

For many years practically all of the wheels used on airplanes were of the wire spoke type, similar to that shown in Fig. I. These wheels have proved themselves to be strong, light, and able to withstand considerable abuse. Wheels of this type are used for high pressure tires and are usually provided with a plain bronze bushing for the axle bearing. Wire wheels are made with a drop center rim to accommodate straight side tires.

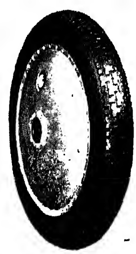


Wire Wheel
Fig. I

Wire wheels should be inspected at least every 20 hours for loose or rusty spokes, rim dents and wheel alignment. Badly rusted spokes should be removed and replaced immediately. Loose spokes should be tightened, as the failure of two or three spokes may cause the misalignment of the entire wheel, possibly resulting in serious damage. Dented rims may be hammered back into shape if the damage is slight. Badly damaged or warped rims should be replaced. The wheels should be removed and inspected for the condition of the bronze bearings. If they are scored or cracked, they should be replaced. If the bearings are worn until the wheel has excess play on the axle, they should also be replaced. All of the old grease should be removed from the wheel bearings, which should then be washed with gasoline to remove any grit or sand. Lubricate the bearings with heavy grease and replace the wheel, making sure the retaining bolt is in place and safetied.

DISC WHEELS

Disc wheels of the type shown in Fig. II are made from pressed dural discs and are somewhat stronger and more streamlined than the plain wire wheel. Disc wheels are equipped with bronze or graphite bearings, as a general rule, although some are furnished with roller or ball bearings. Disc wheels are preferable to wire wheels, especially where brakes are to be installed.



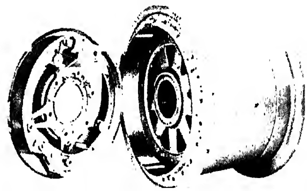
Disc Wheel
Fig. II

Disc wheels require very little attention beyond the protection of the dural. Damaged wheels are usually replaced as it is impractical to attempt a repair of major importance on a wheel of this type. If a graphite bearing is used it should be kept clean and free from any oil or grease. Note: Graphite bearings should never be lubricated with oil or grease, as these lubricants attack the composition of the graphite bearing, causing it to wear rapidly. If bearings other than graphite are used they should be properly cleaned and lubricated every 20 hours.

WHEELS AND BRAKES
(continued)

CAST WHEELS

Low pressure tires have recently become very popular. This type of tire requires a small diameter wheel. Neither the wire wheel nor the disc wheel is satisfactory for wheels of small diameter. For this reason a specially designed cast aluminum alloy wheel such as the one shown in Fig. III, is used. Cast wheels have a removable flange so that the tire may be slipped off the drum. Some wheels are cast in halves and are held together by through bolts. These, of course, must be taken apart before the tire can be removed.



Bendix All Cast Dual Brake Wheel and Hydraulic Brake

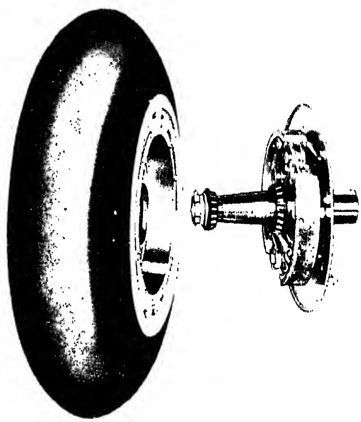
Fig. III

A special aluminum alloy is used in manufacturing cast wheels. When the wheel casting becomes damaged to the point where excessive distortion is noted, or cracks appear in the casting, no attempt should be made toward repair. Very little repair can be made to the wheel itself, other than the replacement of brake drums and bearings.

All bearings, other than graphite bearings, should be kept properly lubricated; however, it is important to see that no excess grease is allowed to accumulate on the wheel. Excess grease is likely to get on the brake drum, which causes the brake to become ineffective, or to "grab".

BRAKES

Brakes are installed on airplanes primarily for the purpose of slowing down the airplane after it has landed; however, since they can be operated individually, they are used as an aid to steering while taxying and to prevent ground looping after landing. A wheel, tire and brake assembly is shown in Fig. IV.



Wheel and Brake Assembly
Fig. IV.

The brakes used on airplanes are much similar to those used on automobiles. They are usually of the internal expanding type, that is, the brake lining is expanded to produce the braking effect by rubbing against the internal drum. When the brake is allowed to con-

WHEELS AND BRAKES
(continued)

tract there is no pressure on the brake drum, therefore the wheel is free to revolve.

There are many types of brake installations, but as a rule they are installed so that they may be operated individually from the cockpit. They are usually arranged so that they may be applied with foot power by pressing the heel down, while the toes remain on the rudder pedal. This is well illustrated by Fig. V showing the type of brake control used on the Stinson "Reliant".

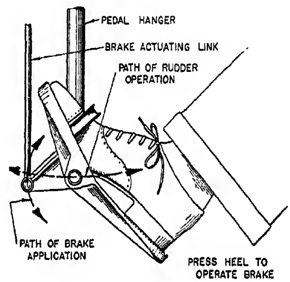


Fig. V

There are two types of brakes used, the mechanically operated brake and the hydraulic brake. The hydraulic brake is considered somewhat more efficient and for this reason it is usually used on larger airplanes. In principle, the operation of the two brakes are alike, the only difference being in the method of applying force to the brake shoe.

The following description and illustrations of brakes are furnished by the courtesy of one of the largest manufacturers of airplane wheels and brakes, The Bendix Products Corporation, of South Bend, Indiana.

"Figure VI shows a line drawing of the hydraulic type brake and Figure VII shows the same of the mechanical brake. It should be noted in both cases that the torque arm "O" of the brake is the basic unit and that no built up or attached members are added for reinforcement of this arm. The torque arm, as well as both brake shoes, is cast of the same alloy used in the manufacture of the wheel, namely, Aluminum Alloy 195.

"With the mechanical brake this torque arm is designed to permit installation of a forged steel operating shaft. One end of this shaft is forged to provide an internal lever "A" (Fig. VII) to which it is attached to the primary shoe through steel link "B".

"In the case of the hydraulic brake the torque arm is designed to incorporate a cylinder "A" (Fig. VI) which is fitted with a thin steel sleeve "S". When hydraulic pressure is admitted to the cylinder, behind piston "P", the force of application is transmitted through connecting link "B" to the primary shoe "C". With both the mechanical and hydraulic brake the primary and secondary shoes are connected by means of a star wheel adjusting screw "D" which has a right hand thread on one end of the screw and a left hand thread on the other; thus permitting spreading or contracting the shoe. All brake shoes for streamline wheel brakes

WHEELS AND BRAKES
(continued)

utilize molded brake lining.

" A take-up cam "F" is provided for adjusting the clearance of the secondary brake shoe. On both brakes the secondary brake shoe "E" is held against the adjustment eccentric by means of spring "H". The purpose of this eccentric "F" is to adjust the clearance between the secondary shoe and drum. As the brake shoes are anchored to the torque arm at only one place "G" it is evident that any variation in the secondary shoe clearance will change the primary shoe clearance. Therefore, the secondary shoe must always be adjusted for clearance by eccentric "F" before the primary shoe is adjusted. After the secondary shoe has been set with correct clearance, the primary shoe may be adjusted by means of star wheel "D".

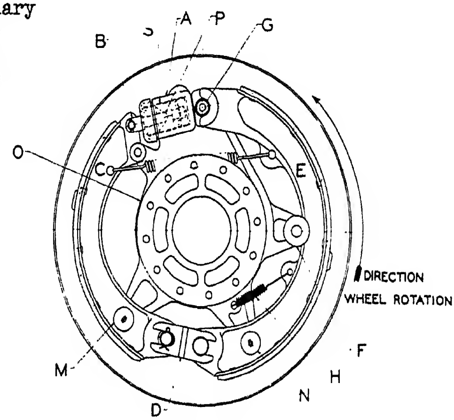


Fig. VI
LINE DRAWING OF HYDRAULIC BRAKE

"The star wheel adjustment "D" is attached to both shoes through pivot nuts. This screw utilizes a right and left hand thread. Each end of it is inserted in a pivot nut of the brake shoe. Thus by turning the adjustment screw the shoes may be drawn together or thrust apart. As the brake drum rotates in the direction indicated by the arrow Fig. VI and VII, the friction between the primary shoe and drum causes the shoe to follow the drum. In so doing the primary shoe, operated through the adjusting screw "D", forces the secondary shoe "E" in contact with the brake drum. At "M" and "N" steady rests are provided for the primary and secondary shoes respectively. The purpose of these steady rests is to keep the shoes in correct alignment with the brake drum.

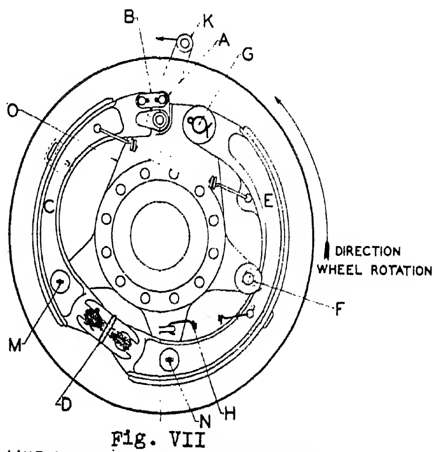


Fig. VII
LINE DRAWING OF MECHANICAL BRAKE

"Adjustment of Brakes.
1. Mechanical Brakes.
a. As the efficiency of

WHEELS AND BRAKES
(continued)

the average brake hookup is not high it is essential that before the brakes are adjusted the hookup be checked over thoroughly. Before attempting to adjust the brake, jack up the wheel and apply the brake several times to be sure the brake releases properly and promptly. If not, the hookup should be gone over carefully, frayed cables replaced, all interference with the cable or control removed, and all pulley and bell crank bearings thoroughly lubricated. The hookup should be tested to ascertain that the brakes release rapidly and with snap to the full off position.

b. Remove the wheel, inspect the brake for damaged parts and the brake lining for grease. If the lining is greasy replace with new lining. If the brake shoe return springs do not have a good initial tension they should be replaced.

c. Inspect the wheel bearing and remove any thin grease. Repack the bearing using a small quantity of heavy graphite fibre grease, and renew the felt washer if necessary.

d. Replace the wheel and the wheel bearing adjustment nut. Be sure there is no brake drag, then with the wheel spinning, tighten the adjusting nut slowly until a bearing drag on the spinning wheel is noticed. Back off the nut to the next castellation and lock in position with a cotter pin. Brake drag should not be confused with bearing tightness while rotating the wheel during bearing adjustment.

The brake should now be adjusted as follows: (See Fig. VIII)

1. Loosen the eccentric lock nut and turn the eccentric in the direction of wheel rotation until the wheel is locked in position. Back off the eccentric until the wheel just rotates freely. With a close fitting wrench hold the eccentric in this position and tighten the lock nut.

2. Uncover the adjusting screw hole by rotating the cover plate and with a screw driver turn the star wheel of the adjusting screw away from the axle until a brake drag is noticed when turning the wheel by hand. Back off the star wheel until there is no brake drag. Replace the cover plate.

NOTE: On brake using the star wheel adjusting screw there is a positive stop provided for the actuating end of the primary shoe which definitely sets the "off" position of this shoe. Therefore, no adjustment is necessary to the brake control lever other than outlined below.

3. The angle between the actuating rod or cable and brake control lever should not be over 80 degrees when the brake is fully applied. This angle should be checked and corrected if necessary, but need not be changed if once corrected as the star wheel adjustment entirely compensates for lining wear.

4. Due to cable stretch, it may be necessary to adjust the

WHEELS AND BRAKES
(continued)

operating cable sufficiently to bring the brake pedal into a position convenient for the pilot to operate.

2. Hydraulic Brakes.

"Bleeding the Line. Whenever the hydraulic line connecting the master cylinder to the brake cylinder is disconnected, air will be admitted to the system and the line must be bled to remove the air. This same condition may develop if the fluid reservoir becomes empty. Air in the line may be determined by action of the brake pedal. If the brake pedal has a spongy action when applying the brake the cause may be due to air compressing in the system.

"It will be noted from figure X, that there are two fittings to the brake actuating cylinder, that is, the inlet fitting and the bleeder. The bleeder is a needle valve with a cap or dust cover on the end.

"To bleed the line proceed as follows:

1. Fill the reservoir with Hydraulic shock absorber fluid, (Lockheed No. 5). During the bleeding operation it will be necessary to check the fluid level in this reservoir several times, never allowing it to become empty.

2. Remove the cap or screw from the bleeder fitting.

3. Unscrew the bleeder valve one-half turn.

4. Prepare a piece of rubber tubing at least 12 inches long and slip one end of the tubing over the end of the bleeder fitting, allowing the free end of the tubing to hang in a receptacle.

5. Operate the brake pedal back and forth slowly, which pumps fluid out of the reservoir and through the system. Continue this operation until the fluid from the hose connection on the bleeder is free of air bubbles. At least one pint of fluid must be pumped through the system before all air is removed.

6. Close bleeder fitting tightly and insert the cap or dust cover.

7. Check the fluid level in the reservoir adding fluid if necessary.

"Brake Adjustment. Bleeding the hydraulic system is not necessary before each brake adjustment, unless there is indication of air in the system.

1. Before attempting to adjust the brakes the wheel should be removed and the brake inspected for damaged parts and the brake lining for grease. If the lining is greasy replace with new lining. If the brake or return springs do not have a good initial tension they should be replaced.

WHEELS AND BRAKES
(continued)

2. Inspect the wheel bearings and remove any thin grease. Repack the bearings, using a small quantity of heavy graphite fibre grease, and renew the felt washer if necessary.

3. Replace the wheel and the wheel bearing adjusting nut. Be sure there is no brake drag. Then, with the wheel spinning, tighten the adjusting nut slowly until a bearing drag on the spinning wheel is noticed. Back off the nut to the next castellation and lock in position with the cotter pin. Brake drag should not be confused with bearing tightness while rotating the wheel during bearing adjustment. The brake should now be adjusted as follows: (See Fig. X for illustration.)

a. Loosen the eccentric lock nut and turn the eccentric in the direction of wheel rotation until the wheel is locked in position. Back off the eccentric until the wheel just rotates freely. With a close fitting wrench hold the eccentric in this position and tighten the lock nut. This should provide a clearance of .010 inch or less at the feeler gauge nearest the eccentric.

b. Uncover the star wheel adjusting screw hole by rotating the cover plate and with a screw driver turn the star wheel away from the axle until a brake drag is noticed when turning the wheel by hand. Back off the star wheel until there is no brake drag. Replace the cover plate. This should give a primary brake shoe clearance at feeler gauge slot of not less than .010 inch.

NOTE: As the actuating end of the primary shoe is provided with a stop to control its off position, the clearance of the primary shoe may be in excess of .010 inch when the lining on this shoe has had considerable wear.

"Adjustment of Mechanical Brake Hookup.

"After the brakes have been adjusted, following instructions outlined under 'Adjustment of Brakes' the hookup should be gone over carefully and the rods, foot pedal, and bell cranks set so that they will be working in the most advantageous position. The brake pedal should be adjusted so that with pedals fully extended and the rudder full on the pedal will be unhindered in operation.

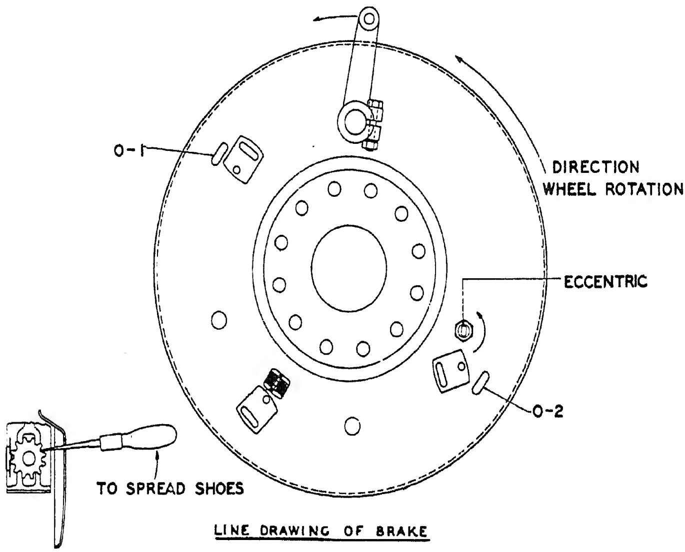
"CAUTION: Brake pedals should be adjusted so as to allow some small movement of the pedals toward the 'on' or braking position before the brakes actually take hold, in order to avoid accidental application of the brakes by the pilot.

"It is recommended that all angles between the cable and rods or bell crank be set at 90 degrees, plus or minus 10 degrees. A good method of determining whether to set this angle at 90 degrees plus 10 degrees or 90 degrees minus 10 degrees; that is 100 degrees or 80 degrees, is to determine the direction of travel of the cable as the brake is being applied. (See Fig. IX) If the indicating arrow denoting direction of travel points away from the lever in question as the brake is being applied, the angle between the cable and

WHEELS AND BRAKES
(continued)

the rod should be 80 degrees. If the arrow points toward the rod or bell crank, the angle should be set at 100 degrees.

"This angle, of course, is to be set with full brake application, and can only be determined by the trial and error method; that is, the brake should be applied full on and the angle checked. If out of position the brake must be released so as to change the position of the rod or bell crank."



LINE DRAWING OF BRAKE

Fig. VIII

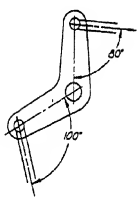


Fig. IX
LINE DRAWING OF BELL CRANK

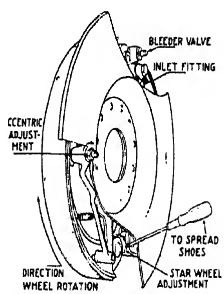


Fig. X
LINE DRAWING OF HYDRAULIC BRAKE

GOODYEAR HYDRAULIC DISC BRAKES

The mechanism in this type of brake is simply a multiple disc clutch, practically the same as that employed in the clutch of some automobiles. A number of bronze discs are keyed, or splined, to the hub so that they rotate with the wheel. Steel discs are arranged alternately with the bronze, so that a steel disc is mounted between each two bronze discs. The steel discs are keyed to the brake anchor bracket. Fig. XI(a) shows the general shape of the bronze disc. The projections around the outside fit into corresponding slots in the hub. The long slots, S, in the disc, assist smooth operation, flexibility, and cooling. Fig. XI(b) shows the steel disc. The notches around the inside fit over splines or keys on the axle shaft, thus restraining these discs from turning. The assembled arrangement is shown in the illustration of the Goodyear Airwheel, Fig. III, in the following section on "Tires."

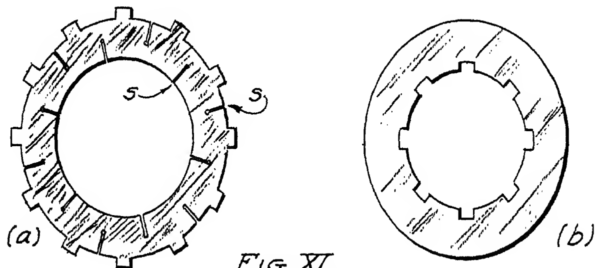


FIG XI

When the brake pedal is operated, the discs are pressed together by an annular piston of approximately the same size and shape as the discs, except that it has no notches or projections. The piston is moved by oil pressure, supplied from a master cylinder, shown in Fig. XII. The clevis on the master cylinder is connected to the brake pedal by suitable linkage. An oil line runs from the outlet of this cylinder to the brake mechanism. Thus, pressure produced by moving the piston of the master cylinder is transmitted to the brake piston, which presses the discs together and "applies the brakes."

The following discussion is quoted from the literature of the manufacturers:

"This type of master cylinder constantly maintains the correct volume of fluid under either extreme heat or cold conditions by compensating for the change in volume due to expansion or contraction. It also automatically replaces any fluid lost through leakage and practically insures against air entering the system due to any leaks.

"The hydraulic pressure necessary to operate the brake is developed in the master cylinder by movement of the piston (6) -- usually by means of the brake pedal.

"Lockheed No. 5 brake fluid is fed by gravity from the supply tank to the cylinder via the inlet port (22) and compensating port (21), and thus fills the master cylinder, the connecting line and on down to the brake cylinder.

GOODYEAR HYDRAULIC DISC BRAKES
(continued)

"Application of the brake pedal causes piston rod (4) to push piston (6) forward. A slight forward movement blocks the compensating port (21) and the building up of pressure begins.

"When the brake pedal is released and returns to off position, the spring (9) returns the piston (6) and front piston seal (10) to the full off position, and again clears the compensating port (21).

"Fluid in the line and brake cylinder is returned to the master cylinder due to the pressure of the brake return springs down at the brake piston.

"Any pressure or excess volume of fluid is relieved by the compensating port and passes back to the supply tank. This insures against the possibility of dragging or locked brakes being caused by the master cylinder.

"If, due to leakage, any fluid is lost back of or to the left of the front piston seal (10), this is automatically replaced by gravity from the supply tank.

"Any fluid lost in front of or to the right of the front piston seal (10) by leaks in the connections, line, or at the brake, is automatically replaced by fluid passing through holes (23) in the piston head and around the lip of front piston seal (10) when the piston makes the return stroke to the full off position. (Seal (10) functions as a seal only during the forward stroke).

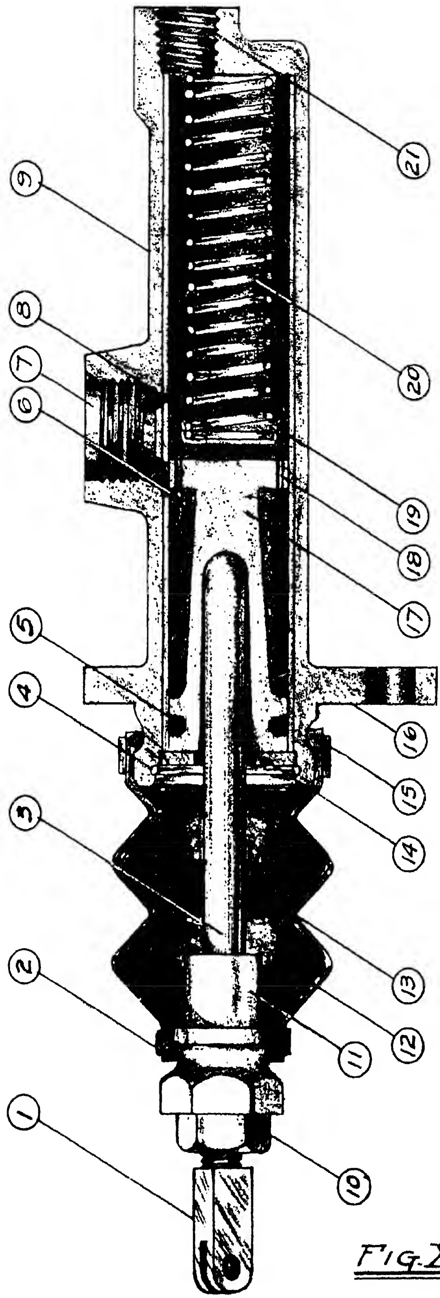
"Consequently, if there is fluid in the supply tank, the master cylinder, connecting line and brake cylinder are always full of fluid and ready for operation.

"Only Goodyear master cylinders should be used with Goodyear Hydraulic Disc brakes. The cylinders have been specially designed with regard to the volume of fluid and the pressure and length of stroke required for that particular braking unit. The airplane manufacturer has designed the brake linkage according to those conditions.

"Goodyear does not recommend installation of Goodyear Hydraulic Disc brakes on airplanes which when designed and manufactured, used any other type or design of brake.

"Rear piston seal (19) seals the rear end of the cylinder at all times and prevents leakage of fluid.

"The flexible rubber boot (12) is only a dust protector."



1. Piston Rod Clevis
2. Rubber Boot Strap
3. Piston Rod
4. Piston Return Stop Lock
5. Rear Piston Seal (Rubber)
6. Gravity Inlet Port
7. Inlet Connection
8. Compensating Port
9. Master Cyl. Casting
10. Clevis Lock Nut
11. Piston Rod Coupling
12. Rubber Boot
13. Boot Air-Vent
14. Piston Return Stop
15. Boot Strap-Large
16. Mounting Bracket
17. Piston
18. Piston Head Ports
19. Front Piston Seal
20. Return Spring
21. Connection to Brakes

FIG. XII

GOODYEAR HYDRAULIC DISC BRAKES
(continued)

It is recommended that maintenance instructions be obtained from the Aeronautics Dept., Goodyear Tire and Rubber Co. Inc., Akron, Ohio, before attempting to service these brakes. However, the instructions below cover the subject in a general way in case no service manual is available.

For satisfactory brake operation, it is necessary, of course that there be no air in the line, as this would mean that depressing the brake pedal would simply compress the air and would not operate the piston. Under normal operation there should be no need for replacing the fluidfor extended periods of time, but if any dirt gets into the system, small particles may destroy the completeness of the seal of either the front or the rear master cylinder. This will cause loss of fluid and possible entrance of air into the line. In this case it will be necessary to flush out the entire system and clean the parts by washing them in alcohol. Do not use gasoline or oil on the rubber parts. This will necessitate bleeding the system to eliminate the air.

The first step in bleeding the system is to fill the supply tank with fluid. This should be regular Lockheed No. 5 Brake Fluid, which may be obtained from most automobile or aircraft service stations. If there is a valve stem in the top of the supply tank an ordinary hand pump may be attached to the valve, the capscrew removed from the bleeder plug in the brake, and a bleeder hose inserted so that the fluid will not be wasted. This procedure is similar to that employed in bleeding the Bendix Hydraulic Brake. The free end of the hose is placed in a clean receptacle, the plug is backed off, and air pressure built up in the tank by means of the hand pump. This will force fluid through the system and the air out. As soon as the fluid comes out in a steady stream without bubbles, the bleeding may be discontinued, the bleeder plug tightened and the capscrew replaced. The pump should then be disconnected from the valve on the reserve tank and the cap replaced on the valve. to keep out dirt. The air vent in the valve cap or elsewhere in the tank should be clear to permit the proper flow of fluid to the master cylinder.

If there is no valve in the supply tank, the procedure is the same through the first few steps. Since no air pressure can be built up on the fluid in the tank the brake pedal must be used to bleed the system. The pedal is pushed down with the bleeder plug open and while the pedal is held down the bleeder plug is closed. The pedal is then slowly moved back to its off position, thus drawing new fluid into the system from the supply tank. This operation of loosening the bleeder plug, depressing the pedal, closing the plug and allowing the pedal to resume the off position is repeated until no more air bubbles come from the bleeder hose. The bleeder plug is then shut off, the hose removed, and the bleeder plug capscrew and washer replaced. The supply tank is checked and new fluid added if necessary. The supply tank cover is replaced and the air vent checked to make sure that it is clear.

If dirt in the system clogs the compensating port in the master cylinder, the pressure on that brake would not be compensated and

GOODYEAR HYDRAULIC DISC BRAKES
(continued)

the brake would pump up after several strokes of the foot pedal and remain locked. If this should happen, the master cylinder should be removed, all parts cleaned, and the small compensating port ahead of the piston checked to see that it is not blocked.

As the discs in the brake wear, a greater movement of the pedal is necessary to apply the brakes. This calls for adjusting the brakes. The wheel is removed from the brake unit and the disc retaining and adjustment nut is screwed up tight and then backed off until a .040" feeler gauge can be inserted between one pair of discs, NOT each pair of discs. The .040" clearance is the sum of all the clearances between the pairs. The disc retaining and adjustment nut is then backed off further to the next locking position and the lock spring installed, taking care that the spring is well anchored in the groove.

If the bronze discs are badly worn they should be replaced with new ones purchased from the manufacturer of the airplane or the Goodyear Company. New discs are installed by removing the wheel from the brake unit, removing the disc adjustment and lock nut, sliding the discs off the brake assembly and replacing the bronze ones with the new discs. It should be noted that a bronze disc must be installed next to the thick steel pressure disc and also that a steel disc goes on last, immediately ahead of the adjustment nut. When the wheel is reassembled to the brake unit the keys which extend from the bronze disc should be lined up with a straight edge and the parking brake lever set to hold them in that position. If the keys are not held in position by the parking lever or by operation of the brake, the rotating bronze discs will move, the keys will shift out of alignment, and it will be difficult to center them in the slots in the hub ring.

In checking the ship for flight, if excessive pedal travel is observed, it is probably due to one of the following reasons; worn discs; improper adjustment of clearance between discs; a leak in the system; air in the system; improper adjustment of the length of the master cylinder piston rod; improper brake pedal setting, or leakage; lack of fluid in the supply tank; air vent in the supply tank blocked; improper bleeding. The remedy for each of these conditions should be obvious from a study of the instructions in the preceding paragraph.

If the pilot reports that the brakes are dragging, the cause is probably one of the following: improper adjustment or clearance between discs; improper adjustment of the length of the master cylinder piston rod; dirt in the system; binding of the brake piston or the dust shield; use of improper brake fluid; weak or broken brake piston return springs; weak or broken master cylinder piston return springs; dished or warped bronze or steel discs; mechanical pedal linkage rusty, jammed, or frozen; parking brake improperly adjusted or partly set. The remedy for each of these is also obvious.

TIRES

Pneumatic airplane tires are very similar to automobile tires in construction, having a soft rubber inner tube inside of a fabric ply gum rubber casing. The casings are usually of the straight side wall type with from two to twelve plies. The inner tubes may be repaired in the same manner as automobile inner tubes, with a cold patch, or by vulcanizing. Boots or blowout patches should not be put in airplane tires as it throws the tire off balance.

Practically all airplane casings have the correct inflation pressure moulded into the side wall of the casing. They should be kept inflated to the correct pressure at all times. This is important, as an under-inflated tire will fully collapse on a hard landing, often causing the inner tube to be cut by the rim and possibly bending the rim flanges. An over-inflated tire may blow out on a hard landing and in any case, puts an undue bursting strain on the rim flanges. Tires should be kept clean and out of the hot sunshine if possible. Never wash a tire with gasoline, nor allow it to stand in grease or oil, as each of these materials is detrimental to rubber.

HIGH PRESSURE TIRES

High pressure tires of the type shown in Fig. I are usually used on drop center rims. They carry, as a rule, from 30 to 60 pounds of air pressure, and are furnished either with or without tread.

MEDIUM PRESSURE TIRES

Medium or intermediate pressure tires, Fig. II, as a class, carry from 15 to 30 pounds of air pressure, and give a much better cushioning effect than do the high pressure tires. Being larger, they offer more resistance than the high pressure tires, but this may be reduced by wheel fairings or pants.

LOW PRESSURE TIRES

Tires that carry pressures of 15 pounds or less are in the low pressure class. This tire is designed to help absorb the landing shock and to improve the airplane's performance on soft or rough ground. This wheel is usually used with a conventional shock absorber unit, but on some light airplanes it replaces that unit entirely. The Goodyear Air Wheel, Fig. III, is a popular example of this class.

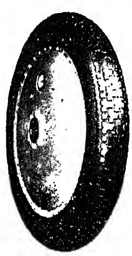


Fig. I

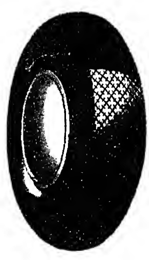


Fig. II

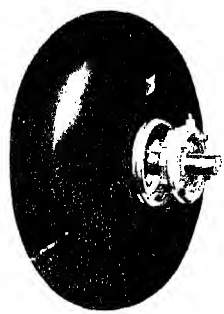


Fig. III

TIRES
(continued)

MOUNTING TIRES

Practically all modern ships are equipped with either medium pressure tires mounted on drop center rims or with airwheels. In the case of the former, the wheel flanges should be examined and any sharp corners or burrs removed with a file. The rim should be clean and free from grease or corrosion of any sort. The first bead of the casing is then mounted on to the wheel at the side opposite the brake drum. The general principle of application is to keep the applied part of the bead as far into the drop center as possible, thus putting the tire on as a buttonhole is put on a button. A flat, thin and smooth tire tool may be used if necessary. After the first bead has been worked on, the tube should be emptied of air by removing the valve core, after which the valve core is replaced and the tube is inserted in the casing with the valve stem pointed outward and located in line with the valve hole in the rim. The tube is then inflated until it is somewhere near its normal size but not stretched. The tube is then worked over the flange using a hammer with the head held in the hand and pushing the tube with the end of the hammer handle, working gradually around the rim. After the tube is on the rim insert the valve stem through the hole and pull up with the valve stem nut, but not too tight. Mount the second bead in the same manner as the first, gradually working around it and taking great care that the tube is not pinched by the tool. After the second bead has been worked onto the rim, the tire may be pumped up to the pressure molded in the casing and the valve stem nut mounted completely.

To demount the tire, the valve nut and the valve core should be removed and the tube completely deflated. The tire beads should be loosened on both sides of the wheel. The bead on the valve side of the wheel is then removed, using two thin, smooth tire tools. The procedure in removing is just reverse of that employed in mounting the tire, the slack being obtained in the bead by keeping that portion which is not yet removed from the tim as far down into the dropped center as possible. When the first bead has been removed, the tube is taken out, care being observed to protect it from damage on any sharp corners that may be on the rim. The second bead is then removed as was the first.

In mounting General Streamline airplane tires, a slightly different procedure is recommended by the manufacturer. The bead ledges of the rim and the tire beads are soaked with a vegetable oil soap. The inside bead of the tire, without the tube, is placed across the outside flange of the rim with the red dot on the casing in line with the valve hole. The bead is started over the rim flange by pounding on the inside of the tire, using a wooden block and a hammer. This pounding is continued around the tire until the entire inside bead drops over the rim flange. The whole inside surface of the casing is then dusted with soapstone or talc. The tube is inserted in the casing with the valve stem at the red dot, after which the valve stem is inserted through the valve hole in the rim by reaching in between the tire bead and the rim. The rim nut is then put on loosely to hold the valve stem in place. (Goodrich tires are also marked with a red dot which should be in line with the valve.) The reason for this arrangement is to keep the tire balanced. The red dot marks the light spot in the casing. This is offset by the weight of the valve. If tires or wheels are out of balance, serious

TIRES
(continued)

vibration is likely to occur just after the take-off.

AIRWHEEL TIRES AND TUBES

The following instructions pertaining to Airwheel tires and tubes are quoted from the manual of the Goodyear Tire and Rubber Co:

"The Airwheel tires and tubes differ from other types of tires and tubes only in the dimensions. Care, and method of operation are similar to tires with which you are already familiar.

"However, the dimensions of the Airwheel are such that considerably greater air volume is available, which permits carrying the load at considerably less pressure than would be the case in tires providing smaller air volume. Consequently, these extra low pressure, super-balloon tires are operated at very low pressure, and for that reason permit operation from soft or rough fields, which would not be possible with any other type of tire equipment.

"Due to the soft air cushion, jolts, vibration, and unusual stresses are absorbed by the Airwheel which assures a comfortable, pleasant ride, in addition to the fact that ship maintenance is lowered. This is due to the fact that the Airwheel damps out and removes shocks and vibrations which normally cause considerable rerigging and regular maintenance expense.

"There is a slight rib at the shoulder of the Airwheel which is called the "inflation rib." When the ship is under full load, enough air should be in the casing so that this rib just meets the ground. By following this practice, it will not be necessary to use an air pressure gauge, and it will be an easy way to maintain proper air pressure.

"These tires are furnished with smooth tread due to the fact that their extra low pressure affords so much more ground contact area that a non-skid design is unnecessary.

"Mounting and dismounting of airwheel tires from the hydraulic type hub is a very easy matter. Remove the valve stem lock nut and valve insides, and deflate the tube. In the 4" size the outside retaining flange can then be pushed inward to expose the wavy lock ring. This lock ring should then be removed and the outer flange can be pulled from the hub. In the larger sizes, after deflating, it is only necessary to remove the nuts from the studs and then remove the flange. After the flange is removed, the tire and tube can be easily removed from the hub.

"With mechanical band type brakes an asbestos lined rubber flap must be inserted between the tube and the hub shell to protect the tube from the heat developed by the brakes. New assemblies have such flaps when shipped. Replacements can be secured from Akron -- specify size.

"Reverse the process for re-mounting the tire and tube on the hub, making sure that the keyways on the tire bead are fitted to the keys on the hub.

"No flaps are needed for tube protection with the hydraulic type assemblies."

ASSEMBLY

It is impossible to give detailed instruction for assembly which will apply to all types of aircraft, yet there is much more general procedure which does have a wide range of application. The following discussion is to be considered as being of a general nature; however, if the principles are understood, the specific details to be observed will become apparent.

Final assembly is usually considered to mean the attaching or putting together the major component parts of an airplane. It is assumed that each of these components is complete, or as complete as possible, before the final assembly is made.

For the purpose of this discussion the major parts are considered to be the fuselage, or hull, the landing gear, the wings, the tail group and the power plant. The order of assembly depends to a great extent upon the design of the airplane. In almost every case it starts with mounting the landing gear on the fuselage. Sometimes the power plant is installed next, as it may be easier to do so before the wings are attached. A careful study of the ship in question will show the most logical assembly sequence.

<u>Tools and Equipment for Assembly</u> - One of the sure marks of an experienced mechanic is that he always gets together all of the tools and equipment that will be needed to complete the job <u>before</u> the job is started. Nowhere does the wisdom of this become more apparent than in final assembly. Picture for yourself the plight of the thoughtless mechanics who, after hoisting an engine into position when all hands are required to steady it, discovers that the necessary bolts are on a bench at the other end of the shop.

Here again it is impossible to enumerate the tools and equipment that will be needed for the specific job, but when selecting them, consider the following items.

Get all fastenings, bolts, nuts, clevis pins, etc., which are necessary to complete the job and place them in a <u>readily accessible</u> position. Make <u>sure</u> that all such fastenings are <u>of the correct</u> size and that the <u>holes</u> into which they are to fit are in good condition. Often a fitting may have inside the bolt hole a slight burr or a film of paint which would make the attachment difficult or impossible.

If the fastenings are to be coated with grease or other substance, this should be done <u>before</u> starting the assembly.

Where any part such as the power plant, wings, etc., is to be bolted to the fuselage, a few bolts of adequate length, but slightly <u>undersize</u> in diameter should be placed in a convenient position so <u>that if an</u> emergency arises they may be used to hold the part temporarily. Needless to say, such temporary fastenings should be conspicuously tagged, or removed and replaced with the proper bolt at the earliest possible opportunity.

An assortment of hammers, screw drivers, drift punches, and a small pinch bar should be included in the assembly kit. The wrenches needed should be selected before starting the job so that no time

ASSEMBLY
(continued)

will be lost in looking for the proper one.

All scaffolding, hoisting tackle, blocking, etc., should be tested and located before using. If the job involves any hoisting or lifting, it is impossible to over-stress the importance of thoroughly rehearsing, mentally, every detail. Insofar as is possible, every contingency should be prepared for. Above all it is important that there be sufficient persons present to do the job and that each man thoroughly understand the part he is to play and also that he know who is to give the directions. Nothing is more confusing and likely to result in disaster than a group on a job of this kind all shouting directions at the same time. If possible, the man in charge of a hoisting or lifting operation should keep himself free of any actual work so that he may be in a position to oversee the entire job and lend a hand when and where most needed.

Landing Gear Assembly - The first step in assembling a landing gear to a fuselage is to hoist or raise the fuselage to a position where the gear can be attached. If sufficient equipment is available, this is best done by attaching a chain hoist to each end of the fuselage and raising it to the desired level. However, even such a simple operation as this requires considerable thought and preparation.

This preparation starts with locating the chain hoists. If two hoists are to be used they should be located directly above the front and rear of the fuselage. The type of hoist which is mounted on an overhead track greatly simplifies the job, but if it must be hung on a cross beam or rafter of the building, care and judgment will have to be exercised to select supports which are strong enough to support the hoists and the weight of the ship. Where the slightest doubt exists as to the strength of the supporting member, it should by all means be reinforced by temporary staging or shoring. An experienced person should be consulted on the reliability of such a structure. The hoist should be attached to its support by a chain of suitable size. The chain should be fastened by putting a bolt through two links, or by the hooks provided for that purpose. Never attempt to tie a knot in a chain.

A good stout rope may be used to attach a chain hoist to its support, but if such is done precautions should be taken to use tope which is strong enough and also to provide sufficient padding to eliminate any possible chafing of the rope. Only safe reliable knots such as the reef knot, bowline, etc., should be used for fastenings.

Regardless of whether a chain or rope is used to fasten the chain hoist, the hanger hook of the hoist should be "moused." That is, after the hook has been passed through the loop of the chain or rope, the open throat of the hook should be closed by wrapping soft wire or twine around the tip of the hook and the shank, as shown in Fig. I.

The lower, or lifting hook of the hoist should be lowered as close to the fuselage as possible and attached by a bridle to the

ASSEMBLY
(continued)

ship. Care should be taken to select lifting points on the fuselage which not be damaged when the load is applied. Conveniently located center section fitting lugs may be used for the attachment of a bridle if the lugs are at such an angle that the bridle load will not bend them. It is often possible to use a strong rope bridle and attach the ends to the motor mount station points. This method is satisfactory if proper padding is provided to avoid cutting the rope. Never attach a rope to a longeron between station points or cluster joints, for the lifting load will impose on the longeron a bending stress which may deform it. Rope attached at a station point should be looped around the longeron at least twice, once on each side of the joint, to prevent any slippage.

FIG. I

Rope or cable should never be passed around a fuselage in such a manner that the lifting load will cause it to cut the covering, or crush the fairing. Many times the best place to attach the lifting sling is to the wing hinge fittings. A bolt or wing pin passed through the fitting and safetied provides an excellent point of attachment. Where such an arrangement is employed, a spreader bar, such as that illustrated in Fig. II should be used to protect the cover from the sling.

After the lifting hook is attached to the lifting sling or bridle it should be moused, as shown in Fig. I.

Before the actual hoisting begins, sufficient blocking and staging should be on hand. Considerable attention should be paid to this detail for the safety of the airplane or even of the mechanic may depend upon the security of the blocking. Only good, sound timbers should be employed for this purpose. Large wood horses may be used to support the airplane if they are known to be of sufficient strength. A little ingenuity will enable the mechanic to design a support which will serve its purpose and yet allow adequate working space to attach the landing gear.

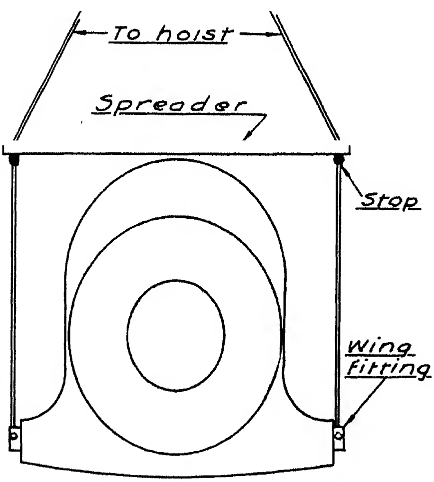


FIG. II

All timbers selected for blocking or staging should be free from knots

ASSEMBLY
(continued)

and splits which might impair their strength. Provide a solid foundation for any support that is used. Avoid using material with rounded corners and do not base a supporting structure on rough or sloping ground,

The staging should be pyramided so that the largest blocks are on the bottom. Each individual block should be placed in its most stable position, so that there will be no danger of its tipping over.

Never use bricks or stones for blocking, as a concentrated load may cause them to crack or crumble.

Place each block in such a position that the weight will be concentrated near its center, to avoid any tendency toward tipping.

HOISTING THE AIRPLANE

After all of the required equipment is in readiness, the actual hoisting may be started. When operating the chain hoist care should be taken that the slack of the overhaul chain is not allowed to rub against any part of the airplane. A scratched surface is one of the least harmful results of such carelessness. Enough men should be used on the hoist chain so that the weight may be raised without undue jerking.

As soon as the fuselage has been raised a few inches, blocking should be placed under it in such a manner as to support its weight in case anything slips or breaks. If this process is repeated for every few inches of lift, the fuselage cannot at any time fall for more than a short distance, thus eliminating the ever present possibility of serious danger to the ship or workmen.

The ship should be raised slightly more than high enough to install the landing gear and blocked in this position. The hoist should then be lowered slightly so that there will be sufficient load on the blocking to insure its stability. The chain hoist should not be removed but left as an additional safety factor.

The landing gear may now be attached as required by the specific case. All bolts should be safetied immediately and all clevis pins cottered. If a tail skid or wheel is used it should be assembled also.

When installing the gear or, for that matter, when working on any job where hoisting or lifting is involved, if it can be avoided do not work under the part which is suspended. Keep all portions of the body clear to avoid being involved in an accident. If it is absolutely essential to violate this rule, take every precaution for personal safety and make suitable arrangements to complete the job in the shortest possible time.

After the landing gear is attached, safetied, and inspected, the blocks may be removed and the ship lowered until it is resting lightly on its gear. At this point the alignment of the gear should be checked. (See section on rigging landing gears.)

ASSEMBLY
(continued)

All cables and hydraulic lines which control the wheel brakes should be connected and the wheels tested for free turning and proper braking. (See section on brakes.) Landing gears of the retractable type may be tested after the rigging has been checked and all plumbing and accessories have been connected. (See discussion of retractable gears.) If the gear is properly aligned and in good working order the chain hoists may be removed entirely.

INSTALLING THE POWER PLANT

Installing the power plant involves hoisting the engine and attaching it to the engine mount, connecting all plumbing and electric lines, attaching cowling, etc. Work of this nature falls more within the scope of the engine mechanic, therefore the discussion here will be confined to preparing the airplane for the installation. A detailed description of power plant installation will be found in "Aircraft Engine Maintenance" - (Pitman).

In conventional types of airplanes it is usually easier to install the engine when the airplane is level. After the engine is hoisted to the proper level the airplane is moved into position and the tail raised. Before the engine is attached, the landing gear wheels should be blocked both front and rear, and if a parking brake is provided it should be set and locked.

Suitable support should be provided for the tail of the ship. The tail should be lashed in position so there will be no possibility of its swinging. It must also be securely anchored so that the weight of the engine will not cause the ship to nose over. If there is no anchorage suitable for lashing the tail down, heavy weights may be hung on the tail to prevent nosing over. Where this is done, due precautions should be taken to see that the weights are heavy enough and that no portion of the covering, fairing or other part will be damaged.

After the engine has been installed, the tail may be lowered to the ground. It may be that the tail is so light that the ship may still be in danger of nosing over, especially if the propeller is mounted on the engine or if a workman should stand on the ship ahead of the wheels. If there is any doubt, the tail should be firmly lashed or weighted.

ASSEMBLING WINGS

Many biplanes have center sections which must be mounted before the wings can be assembled. If the center section is not too heavy it can be installed by hand, otherwise it will be necessary to rig a chain hoist or block and fall arrangement so that it may be hoisted and swung into position. A small center section is most easily mounted by attaching the struts to the section while it is still on the ground. Suitable platforms are placed on each side of the ship in such a position that they will afford standing and working space.

After the struts have been attached to the center section, all cowling and inspection plates which are to be installed <u>over</u> the

ASSEMBLY
(continued)

struts must be put in position or placed where they are readily accessible to slip over the struts before the struts are attached to the fuselage.

When everything is ready the section can be lifted and supported by the struts. If possible, there should be one man on the lower end of each strut to hold and steady the section and another mechanic to bolt the struts to the fuselage. After the struts are secured, the cross wires or tierods should be attached before the section is released. All bolts and clevis pins should be safetied and all the tierods tightened at least to a safe distance before the job is left.

In many cases it is more desirable to rig the center section before the wings are assembled. This is especially true of those sections that have adjustable struts which must be removed in order to make the adjustment. Directions for rigging center sections are given later in this section.

When the center section is in place and rigged (if required), the wings may be assembled. On a biplane it is better to put the lower wings on first if the landing wires are attached at the upper end to the center section fittings. Such being the case, attach the left hand thread end of the landing wires to the center section fittings. (Note: It is customary to install all tierods so that the right hand thread is down, or toward the front.) The lower wing is merely lifted and held in position. Ordinarily, no platforms or scaffolds are needed, as the wing attachments are usually within easy reach. Before actually attaching the wing, make sure that all wing connections such as aileron cables, lights, air speed tubes, etc., are connected or are in a position to be connected after the wing is installed.

After the wing is attached, the landing wires are connected and the other lower wing assembled. No blocking under the tips of the wings is required, for the landing wires will support them.

To assemble the top wings, attach the struts to the wings and make sure that all inspection plates, fairings, etc. which cannot be installed after the struts are connected on both ends, are in place. Scaffolds should be arranged which will permit the wing to be held in position and will yet allow working space. An adjustable rack to support the wing tip can be made by clamping a cross bar to two upright members. The cross bar should be about two feet longer than the chord of the wing and padded to protect the wing covering. (Fig. III.) The lower ends of the uprights should be anchored in some manner.

When lifting the top wing into position care should be taken not to allow the struts to swing violently, possibly imposing a bending stress on the fittings or damaging the covering of the upper or lower wing. As soon as possible, a pin or undersize bolt should be used to fasten temporarily the lower ends of the struts to the fittings on the lower wing. This will steady the wing and yet allow enough freedom of movement to permit alignment of the hinge fittings. If there are any connections to be made from the top wing to the

ASSEMBLY
(continued)

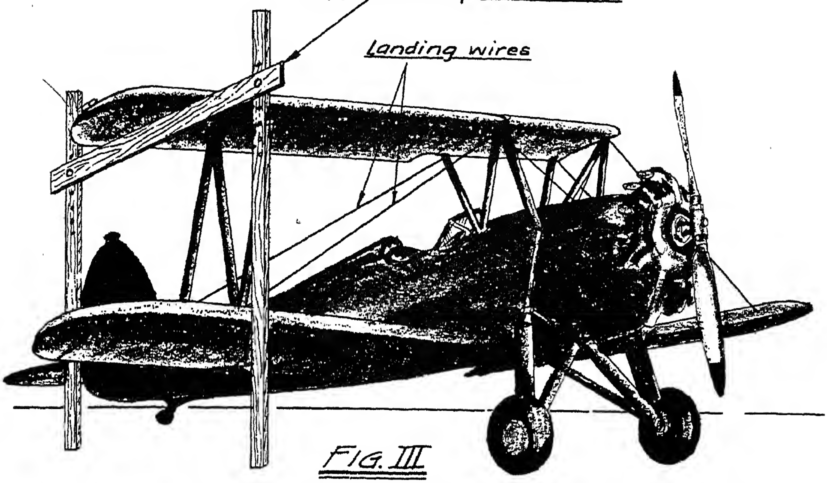


FIG. III

Support for Assembling Top Wings

center section, such as aileron balance cables, electrical cables, etc., they should either be connected before the wing is attached permanently, or placed in a position where they can be connected after the wing has been attached. The wing pins may then be installed and safetied.

The temporary fastenings in the lower ends of the struts may then be removed and replaced with the permanent ones. Although there is no such definite rule it is customary to place the bolts in the interplane struts so that the nuts may be seen from the cockpit. After the permanent fastenings have been made, the wing support may be removed, and the flying wires installed. The top wing on the other side is assembled in the same manner. The wings are then ready to be rigged (see section on Rigging).

If the landing wires are attached at the upper end to fittings which are anchored in the top wing, it is better to put the top wing on first. The upper wing with the struts attached is installed on the center section and supported by standards similar to those shown in Fig. III. The upper ends of the landing wires may then be connected and tied roughly into position at the lower ends with a light string. This is for the purpose of having the landing wires in readiness to be attached to the lower wing, and yet holding them where they will not interfere with the assembly. The lower wing is attached to the fuselage as previously described and the interplane struts bolted in place. Landing wires may be attached next, the support removed, and the flying wires installed.

ASSEMBLY
(continued)

Although the foregoing discussion pertains more directly to the assembly of wings on a biplane, it may in general be applied to attaching the wings of a monoplane. In the case of a parasol monoplane in which the wing is made in one piece, it is probably better to hoist the wing to the desired level and run the ship under the wing to complete the assembly. If no lifting eyes are provided on the wing, the wing should be lifted by padded cross beams. One of these should be located on each side, slightly more than halfway from the center to the wing tip. Bridles lead from these beams to the hoist. Great care should be taken, however, to avoid causing the cross beams to slip by lifting one end of the wing more rapidly than the other. The load struts should be installed at the earliest possible moment in order to reduce the possibility of mishap.

ASSEMBLING THE TAIL GROUP

It is usually more convenient to assemble the tail group while the tail skid or wheel is resting on the ground or a low block. As ships vary in design, it is impossible to list the correct sequence for installing the parts of even the conventional empennage. However, in most cases the horizontal stabilizer should be attached first. If it is of the adjustable type, all points which pivot or rotate should be lubricated before assembly. The adjustable control mechanism should be attached, tested and safetied before assembling the other parts.

An examination of the construction details will indicate whether the elevators or vertical fin is to be installed next. Such an inspection is quite necessary, for on some ships the elevators cannot be installed until after the fin, while on others the opposite holds true. After these parts are installed the rudder may be assembled and all brace wires attached. Connection of the control cables completes the assembly of the tail group, which is then ready to be rigged.

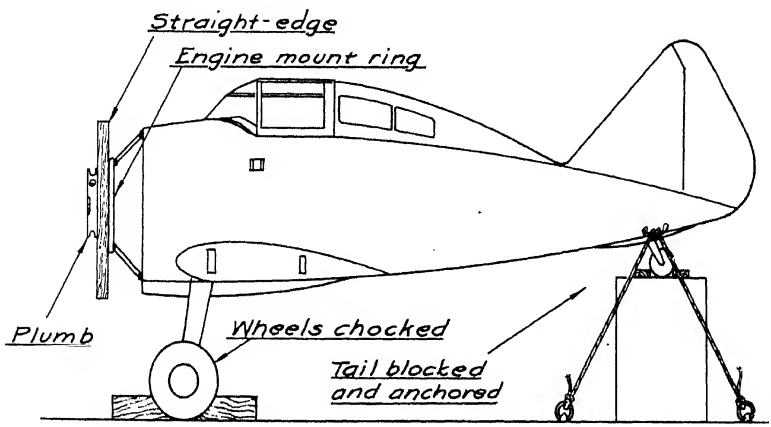
RIGGING

Although modern airplanes as a class require less rigging than those of the older types, it is still just as important for the mechanic to understand the theory of rigging, if only for the purpose of checking the alignment of a ship. In many respects it is more difficult to make such a check on a modern airplane than it was to do the same job on earlier types for the reason that the streamlined fuselages, tapered wings, etc., do not provide any convenient leveling and rigging points. On the other hand, if the principles involved are understood, the alignment of any ship can be checked.

In the foregoing discussion of final assembly it was assumed that the alignment of each of the major component parts was correct. If, however, a ship is being assembled after a major overhaul, the alignment of every part should be checked before final assembly.

Checking Fuselage Alignment - The alignment of a fuselage is most easily checked by first placing the fuselage in "flying position", or level longitudinally and laterally. This is a simple job if it is known what portions of the ship can be used for checking points. For example, the top longerons on many airplanes are parallel to the line of flight. Thus, by placing a spirit level on the longeron and raising the tail of the ship until the bubble in the level is between the reference marks, the ship is levelled longitudinally. Likewise, by placing the level on a cross tube which runs between the two longerons, and raising one side of the ship or the other, the fuselage may be levelled laterally.

However, if longerons or cross tubes are used as a means for leveling, no one point should be considered satisfactory unless that point has been specified by the manufacturer. Rather, a reading of l should be taken at several positions and, if necessary, a compromise made.



- LEVELLED

RIGGING
(continued)

Most modern airplanes have leveling points which are attached or installed by the manufacturer at the time the ship is built. These points may be short sections of tubes welded directly to the fuselage, and upon which a level or straight edge may be placed. They may consist of two horizontal lines inscribed on metal plates mounted directly on the fuselage at a short distance apart: or they may be two tapped plates welded to the fuselage. In the latter, by threading a long bolt or stud into each plate a support is provided for the level. If leveling points are provided, the type and position of such points is described on the manufacturer's rigging specifications, otherwise they may often be located by inspection, being found usually on the left side of the fuselage, a short distance behind the firewall.

Placing a fuselage which does not have convenient leveling points, in flying position is a somewhat more difficult job. However, if it is clearly understood that "flying position" means the actual position the ship will assume when in level flight, then points can be established which will serve the purpose. For example, when leveling a fuselage such as that shown in Fig. I, where it is known that the line of thrust is parallel to the line of flight, a plumb bob may be suspended in front of the engine mount and the tail of the ship raised until the engine mount is parallel with the plumb line. This levels the ship longitudinally. Another method is to place a straight-edge across the engine ring in a vertical position and hold a spirit plumb-level on this. The plumb will indicate when the engine ring is in a vertical position. (See Fig. I.) To level the ship laterally, it is often possible to place a straight edge across the two top firewall-engine mount fittings and lay a level on the straight-edge. If this cannot be done, lateral leveling points can be secured by placing two spacer-rods or blocks of exactly the same length on the wing root fittings, and placing a straight-edge on the blocks, as shown in Fig. II. In the case of a low wing ship the measurement may be taken from underneath the fuselage.

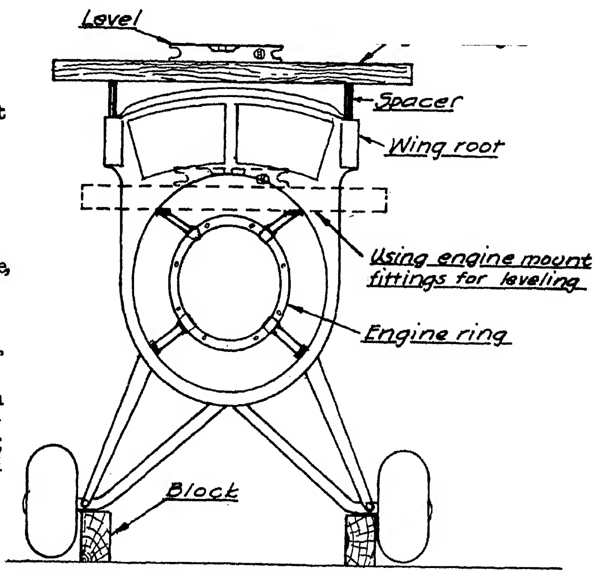


FIG II LEVELLED LATERALLY

RIGGING
(continued)

Never select non-structural members for leveling purposes. Any such parts which may appear suitable, such as floor boards, seats, cowlings, window frames etc., may be only approximately level and their use will produce erroneous results.

The actual checking of the fuselage alignment can be accomplished after the ship is in flying position, by means of a longitudinal reference line, plumb bobs and a trammel. The following items are to be checked:

1. The symmetry of the fuselage, or the equidistance of the various station points to the centerline.
2. Alignment of the vertical plane, to ascertain if there is any warp or twist in the fuselage.
3. Alignment of the transverse plane, to determine if the fuselage has been bent up or down.

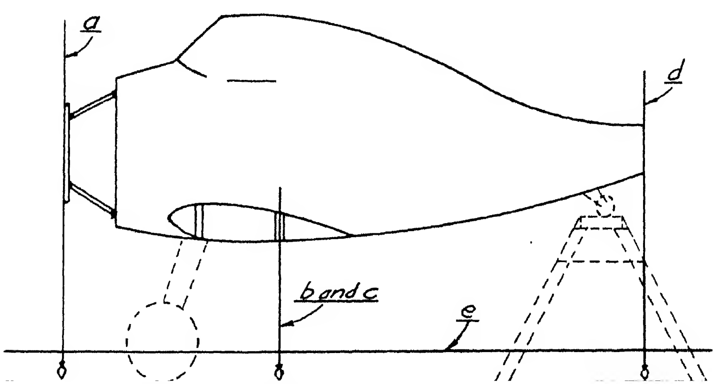
It is difficult to check the alignment of a covered fuselage properly, for it is impractical to obtain accurate reference points. However, if it is badly out of alignment this can be detected, in most cases, by the method described below.

Checking Alignment of Covered Fuselage -

1. Place the fuselage in flying position.
2. Drop a plumb line from the center of the engine mount (Fig.III-a).
3. Drop plumb lines from each of the rear hinge fittings. Call these lines (b) and (c).
4. Drop a fourth plumb line from the top of the tail post (Fig. III-(d)

Stretch a line (e) lengthwise of the fuselage in such a manner that it just touches the plumb lines (a) and (d). Fasten the line in this position by tying each end to some solid support.

With a trammel or other suitable means measure the horizontal distance from lines (b) and (c) to the centerline (e). If the



'IG. III - CHECKING

RIGGING
(continued)

fuselage is true, the distances will be the same. If there is any difference in the measurements, check back over all the lines to make sure that no error has been made there.

7. If it is possible to obtain any other reference points which are established at points equidistant from the centerline of the fuselage, drop plumb lines from these points and check the horizontal distance from them to the centerline (e). Some suitable points would be fuselage station joints, front spar hinge fittings, etc.
8. Inspect the line (d). It should be parallel to the tail post. If it is not, it indicates that the fuselage is twisted. Before assuming this, however, check again to make sure that the fuselage is still level laterally.

Where any misalignment is found which would indicate serious trouble, the fuselage should be taken to an approved repair station where it can be uncovered and given a thorough check. Inasmuch as there are few, if any, fuselages today which can be realigned, or rigged, by adjusting turnbuckles or tie-rods as was done with the older ships, the realignment of fuselages will not be discussed here.

RIGGING LANDING GEARS

There are few modern wheel-type landing gears that require rigging. They are designed to be attached to the ship by struts of exact length which, when properly connected, automatically assure correct alignment. However, there are some which are braced or partially braced by adjustable struts or tie-rods. The rigging of such gears can usually be accomplished by adjusting each corresponding pair of struts or tie-rods so that the trammeled distance from pin to pin is the same.

It is desirable to check the alignment of any gear which has been rigged in the above manner. The alignment may be checked, roughly, by placing a straight-edge across the rims or tires of each wheel, as shown in Fig. IV. If the distance (a) is equal to the distance (b), it indicates that the wheels are parallel to each other, but does not show if they are parallel to the centerline of the ship. To determine this, a centerline will have to be stretched under the ship as was done when checking fuselage alignment (Fig. III). The distance from each end of the straight-edge to the centerline

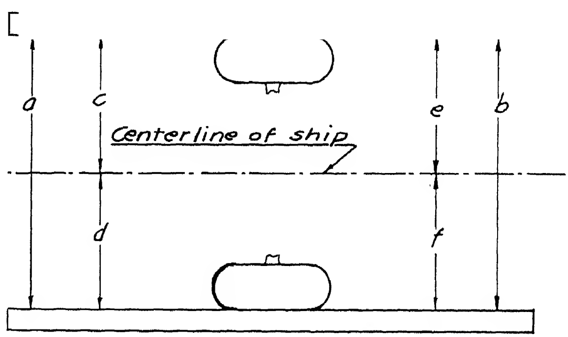


FIG. IV - WHEEL ALIGNMENT

RIGGING
(continued)

should be equal, or (c), (d), (e), and (f) must all be the same.

A less accurate but more rapid method of testing wheels to see if they are parallel to each other, is to jack up each wheel and spin it. As the wheel is rotating, mark a line around the circumference of the tire by holding a pencil steadily against it. Mark both wheels in this fashion. Remove the jacks and measure the distance from the pencil line on one wheel to the corresponding pencil line on the other wheel, at both the front and rear. The distances, of course, should be the same.

If twin floate are installed on the ship, the rigging specifications furnished by the manufacturer should be followed. If no such directions are furnished they can be obtained from the manufacturer of the floats for a small sum. The manufacturer will have to know the serial number of the floats and the type of airplane on which they are to be installed. In general, floats are to be parallel to each other and also parallel to and equidistant from the centerline of the airplane. However, the exact specifications should be consulted, for if not properly rigged, floats may seriously affect the performance of the plane.

RIGGING CENTER SECTION

The tools and equipment needed to rig a center section consists of plumb bobs and lines, steel tape, trammel, spirit level, level protractor, straight-edges, and an assortment of wrenches, including tie-rod wrenches and any special wrenches that may be needed to adjust the struts. A set of rigging specifications should be obtained from the manufacturer of the ship. Where no specifications are available, the mechanic will have to exercise his judgment as to the proper alignment.

Many biplanes have center sections and, where such is the case, the center section should be rigged first. The first step in rigging a center section is to locate it so that the longitudinal centerline of the section is directly above the centerline of the ship. To do this, adjust the cross wires (a) and (b) in Fig. V until they trammel the same from pin to pin. If the length of the wire (a) is greater than that of wire (b), loosen the wire (b) and

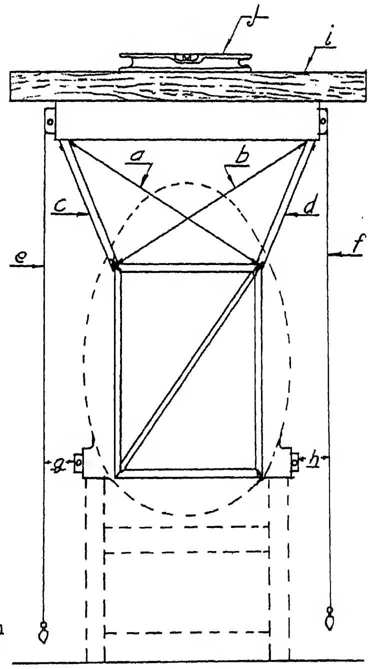


FIG. V

RIGGING
(continued)

tighten the wire (a). (Note: When adjusting wires that are in tension, always loosen one wire before tightening the opposing wire). When wires (a) and (b) are adjusted to equal length the center section is in the middle of the ship, if the struts (c) and (d) are not adjustable. If they are, they should be adjusted until they measure the same from bolt to bolt, before attempting to adjust the cross wires.

To check the accuracy of the work, drop plumb lines (e) and (f) from the upper hinge fittings and measure the horizontal distance from the lines to some structural part, such as the lower hinge fittings. Obviously, if the ship is level laterally and the center section is in the middle, the distances (g) and (h) will be the same.

Next, place a straight-edge (i) directly over the front spar in the center section and place a level (j) on it. If the center section is not level, the struts (c) and (d) should be readjusted. If they are of equal length and the center section is not level, the misalignment may be due to improper stagger. To check this, drop a plumb line (Fig. VI-a) over the leading edge of the center section near each end. The distance (b) from the plumb line to the front hinge fitting should be the same on both sides. If the lower wing is on, the measurement may be taken from the plumb line to the leading edge of the lower wing. The measurement thus obtained is called the "stagger." If the stagger is greater on one side than on the other, the stagger struts (c) should be adjusted. For example, if the stagger is too great on the left hand side, the strut (c) should be shortened; if too little, the strut should be lengthened.

It will be noticed that when the stagger is changed, strut (d) pivots on point (e) and describes an arc, shown by the dotted lines at the top of strut (d). Thus, any change in stagger will affect the horizontal level of the center section.

After locating the center section above the centerline of the fuselage, leveling it and adjusting the stagger on both sides, the next step is to make sure that it is not twisted in its horizontal plane. In other words, make sure that the chord line of the butt ribs on each side of the ship form the same angle with the line of flight. This operation is known as checking the "angle of wing setting."

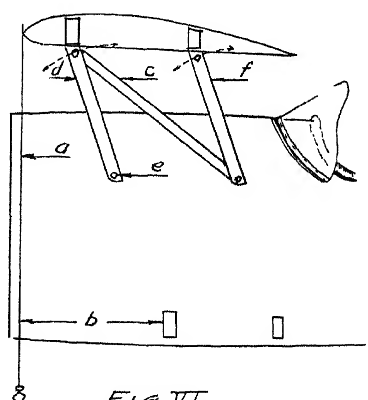


FIG. VI

The angle of wing setting is the acute angle formed by the chord line of the wing and a horizontal reference line. However, inasmuch as it is sometimes difficult to determine the exact chord line, for purposes of

RIGGING
(continued)

rigging the angle of wing setting is usually accepted to be the acute angle formed by the base line of the airfoil and a horizontal reference line. To determine this angle, make sure the airplane is level longitudinally and place a straight-edge which is longer than the chord along the bottom surface of the airfoil, as shown in Fig. VII-(a). Make sure the straight-edge is on a rib, then hold a level protractor (b) in the position shown. Adjust the inner, movable portion of the protractor until the spirit level, which it contains, reads level. Lock the protractor in this position and read the angle, thus measured, directly from the graduations marked around the circumference of the instrument. In the same manner, take a reading from the other end of the center section, and if the two angles are not the same it shows that the section is twisted in its horizontal plane.

If the angle of wing setting of the left side of the center section is greater than that of the opposite side, and as the front struts were previously adjusted to equal length, the difference should be corrected by lengthening strut (f), or by shortening the opposite rear strut.

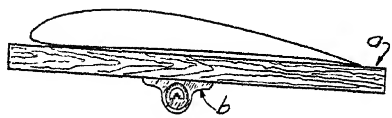


FIG. VII

If rigging specifications are available, exact information will be given as to where and how the angle should be measured and what the measurement should be. Otherwise, it may be assumed that the angle of wing setting for the center section is to be the same as for the bottom wing. By taking a measurement of this angle from the bottom wing close to the hinge fittings, a reasonably accurate result may be obtained.

Frequently, the mechanic is not concerned with what the angle of wing setting is as long as it is the same on both sides of the center section. A method of checking the equality of the angles without the use of a protractor is to construct an "incidence board", as shown in Fig. VIII. A straight-edge (a) is placed on the airfoil, and a level placed in the position shown in (b). A block (c) is placed directly over the rear spar and clamped to the straight-edge after the rear of the straight-edge has been raised until the level (b) shows level. A position mark (d) is made on the straight-edge so that it can be placed in a similar position each time a reading is taken. By placing the incidence board and level at various points along the center section or wing, it can be determined whether the angles of wing setting of the points thus measured are greater or less than at the original point.

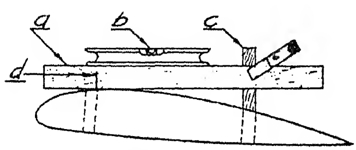


FIG. VIII

After the above points have been checked, and all struts and tie-rods have been locked and

RIGGING
(continued)

safetied, the rigging of the center section can be regarded as complete. Many center sections do not require as much rigging as has been described, for they may have non-adjustable struts, making it impossible to adjust each angle. In this case the rigging is limited to adjusting the tie-rods so that they are the same length from pin to pin. Nevertheless, the importance of the alignment of the center section cannot be over-emphasized, for if this alignment is not correct, it will be impossible to rig the wings correctly, and the flight characteristics of the ship may be impaired.

RIGGING WINGS

When rigging the wings on a biplane all of the flying wires should be slacked and the lower wings rigged first, for dihedral. Dihedral is commonly understood to be the acute angle formed by a transverse reference line in the wings and a horizontal reference line, and is measured in the vertical plane. On the conventional biplane the front spar of the wing is usually accepted as being the wing reference line. Therefore, the angle of dihedral can be measured by placing a straight-edge along the front spar, holding a level protractor on top of this and adjusting and reading the instrument, as illustrated in Fig. IX. Tightening the landing wires increases the dihedral and conversely, loosening the landing wires decreases dihedral.

Many biplanes have from 1° to 4° dihedral in the lower wings and 0° dihedral in the upper wings. When such is the case the simplest procedure is to rig the top wing straight, or level transversely. To do this, place two blocks (Fig. IX-a) on the front spar, directly over the last full sized rib, and stretch a string (b), as shown. Adjust the landing wires so that the distances from the string to any corresponding portions of the wings or center section are the same. As a check, sight along the leading edge to see if that is straight also.

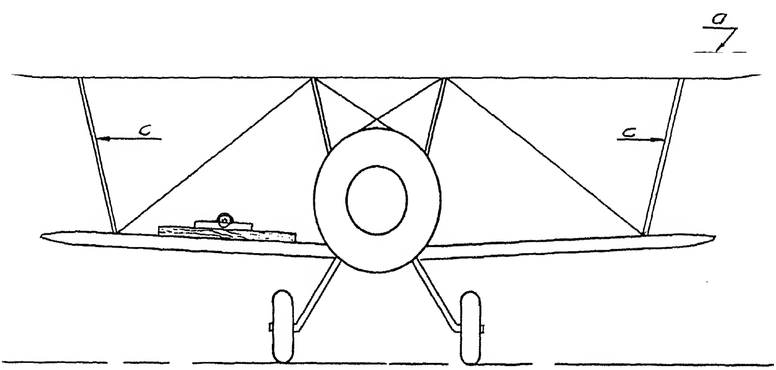


FIG. IX

RIGGING
(continued)

It will be noticed that when the upper wing is adjusted to 0° dihedral, the position of the lower wings will be determined by the length of the interplane struts (Fig. IX-c). If the front strut is not adjustable, the lower wings must have the correct amount of dihedral.

If the front strut is adjustable, the proper procedure is to rig the proper dihedral in the lower wings by means of the landing wires, and then raise or lower the outer end of the top wing by increasing or decreasing the length of the struts.

Regardless of which method is used, remember that the basic adjustment to be made is the dihedral angle of the front spar of each lower wing. After this has been done, no wire or strut should be adjusted which will change this angle.

The next step in rigging a biplane is to adjust the wing setting of both lower wings so that they are perfectly true in their horizontal plane, or so that the angle of wing setting at the last full rib is the same as that of the butt rib. If the angle at the wing tip is too great, it may be decreased by tightening the rear landing wire. The angle of the wing may be measured at any point with a straight-edge and protractor as previously described under "Rigging the Center Section", or an incidence board and level may be used to make sure that the angle of wing setting is the same along all portions of the wing.

The stagger of the wings may be checked by dropping a plumb bob over the leading edge of the top wing and measuring the horizontal distance from the line to the leading edge of the lower wing. If the stagger is being set to a manufacturer's specification, make sure that the airplane is in the position which the specifications require. For example, some specifications give the stagger in inches when the ship is in flying position, while in others the stagger is specified for the ship in landing position. A convenient method for supporting the plumb line is to tie it to the top of a long pole which can be held above the wing or laid against it, in such a manner that the plumb line rests firmly on the nose section. If any difficulty is encountered in taking the actual measurement, due to the continuous swinging of the plumb bob, the line can be steadied by allowing the plumb bob to descend into a pail of water. However, care should be taken that it does not touch the bottom or sides of the pail. Inasmuch as the stagger of the center section has been previously adjusted, a mere check should be sufficient at that point. Next, check the stagger at a point directly in front of the interplane strut. If the stagger is too great, increase the length of the diagonal, or stagger, strut (Fig. X-a). The stagger can be increased by shortening the same strut.

Referring to the diagram in Fig. X, it will be seen that when the position of the top wing is moved, the struts (b) and (c) will pivot at their lower ends and their tops will describe the arcs indicated by the dotted lines. If the struts and their attachments are so designed that the center lines of the struts are parallel, and the distance between the chord lines of the wings is the same,

RIGGING
(continued)

the angle of wing setting of the top wing will not be changed by an increase or decrease of stagger. If it is not so designed, an adjustment will be provided in strut (b) or (c), or both. Thus, if an adjustment is provided in strut (b), the next step in the rigging is to adjust the dihedral angle of the front spar of the upper wing. This will be done by increasing or decreasing the length of the front strut (b).

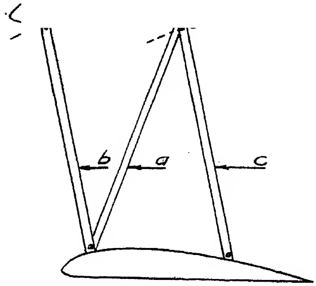


FIG. X

Check the angle of wing setting of the upper wing and adjust it by means of strut (c) so that it is the same at all points. If it is too great at the wing tip it can be decreased by raising the rear spar. In order to raise the rear spar without affecting the previously established stagger, both the stagger strut (a) and the rear strut (c) will have to be lengthened proportional amounts. Conversely, the angle of wing setting can be increased by shortening both struts.

After the above described adjustments have been made, the flying wires can be tightened to the proper tension. Before proceeding further, the angle which the wings form with the fuselage should be checked to make sure that no undue strain has been placed on any member. To do this measure from some corresponding point, such as the interplane strut fittings, to a central point located in the nose of the ship. Such a point might be the centerline of the engine mount, or the tip of the propeller hub. Needless to say, the measurement of the right hand side should be the same as that of the left hand side. If a difference of more than 1/4" is discovered, the entire rigging should be re-checked.

The final step in rigging biplane wings is to adjust the wash-in and wash-out for counteracting the effects of torque (torque is described elsewhere in this book). It is common practice in biplanes to put wash-in and wash-out in the bottom wings only. In the conventional biplane with a counter-clockwise rotation engine, the left lower wing should be washed in. Referring to Fig. X, this would be done by loosening the rear landing wire and lengthening the rear strut (c). If the exact amount of wash-in is not given it is safest not to increase the angle of wing setting more than one degree. If it is desired, the right hand lower wing may be washed out by shortening the rear strut and tightening the rear landing wire. After these final adjustments have been made, all strut adjustments should be locked, and all tie-rods streamlined and safetied.

To summarize, the proper sequence for rigging the wings of a biplane may be outlined as follows:

1. Set the dihedral angle of the front spars of both lower wings.

2. Rig equal wing setting angles in lower wings by changing dihedral

RIGGING
(continued)

of rear spar (if necessary).

3. Set the stagger.

4. Adjust or check the dihedral angle of the front spars of upper wings.

5. Rig wing setting of upper wings by adjusting rear spar.

6. Check wing-fuselage alignment.

7. Set wash-in and wash-out.

8. Re-check all points and safety all tie-rods, struts, and adjustments.

RIGGING MONOPLANE WINGS

There are many types of monoplane wings which cannot be rigged outside of the factory. However, those which are provided with adjustable struts may be rigged on the field. As with the biplane, the first step in rigging is to adjust the dihedral angle of the front spar. If rigging specifications are available, the amount of dihedral and the method of determining the angle will be given. In the majority of cases the dihedral angle may be measured by placing a straight-edge and level protractor on the front spar, as was done in the case of a biplane. If the amount of dihedral is not known, it is usually considered safe enough to adjust it to the mid-position. For example, if it is possible to adjust the dihedral from 2^{o} to 8^{o}, for purpose of trial, it should be set at 5^{o}.

An inspection of the lift strut arrangement will disclose the method to be used in adjusting the angle. Struts which support the wing from above, as in the case of a low wing monoplane, should be shortened to increase the dihedral. Struts which support the wings from below are lengthened to increase the dihedral.

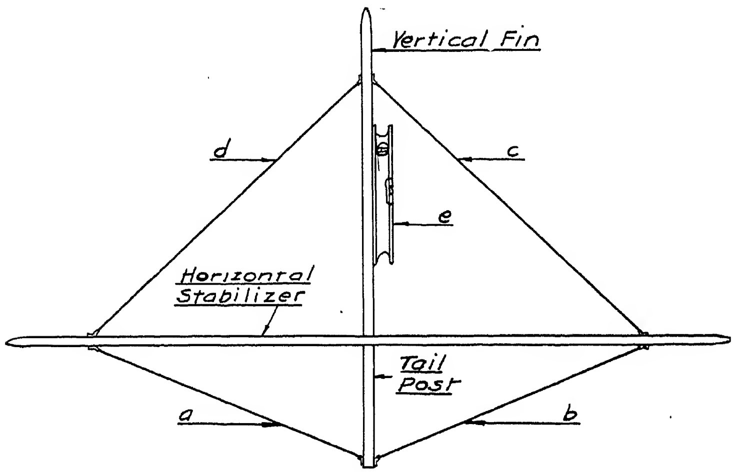
After setting the dihedral of the front spar, check the angle of wing setting of the entire wing. It is more convenient to adjust the position of the rear spar to give a constant wing setting at all points and then add a slight amount of wash-in and wash-out to counteract for propeller torque. Locking and safetying of all strut adjustments and tie-rods completes the rigging of monoplane wings.

RIGGING THE TAIL GROUP

Probably the most important alignment in the tail group is that of the horizontal stabilizer in relationship to the wings. Before attempting to rig this surface, the lateral position of the ship should again be checked to make sure it is still level. The rear member of most stabilizers is designed to be levelled laterally. This may be measured by placing a straight-edge and spirit level directly on the rear member.

RIGGING
(continued)

vertical fin is designed to be at 90° to the plane of the stabilizer, therefore the alignment of the vertical fin and the horizontal stabilizer will, in most cases, have to proceed at the same time. If the tail group has tie-rod bracings similar to those shown in Fig. XI, a common method of procedure is to adjust wires (a) and (b) so that they trammel the same length from pin to pin. Next, the



wires (c) and (d) are adjusted so that they are at the proper tension and so that they also trammel the same length from pin to pin. Theoretically, this will assure that the rear member of the vertical fin is parallel to the tail post of the airplane and consequently in a true vertical position. This alignment can be checked by holding a plumb level (e) against the rear post of the fin, as shown in Fig. XI. A more exact method of testing this alignment is to suspend a plumb bob from the top of the vertical fin post and visually inspect its position with reference to the hinge fittings on the fin and tail post. This latter method can be employed only before the rudder has been attached.

If the vertical fin is plumb, the stabilizer may be leveled by adjusting the wires in pairs. For example, if the level shows that each end of the stabilizer is low, wires (a) and (b) should be loosened equal amounts, that is, by counting the turns that each wire is loosened. By tightening wires (c) and (d) by exactly the same number of turns, the ends of the stabilizer will be raised without changing the alignment of the fin or the final tension of the wires.

If the elevators have not been assembled to the stabilizer, a string may be stretched from the outer hinge fitting on one end of the stabilizer to the corresponding fitting on the other end, thus

RIGGING
(continued)

checking the alignment of the hinge fittings. This is important, for even a slight misalignment may result in stiff movement of the elevators.

If the front of the vertical fin can be adjusted laterally (to counteract the effects of unequal drag on the wings, as described elsewhere in this book) it should be moved to the correct position and locked. If the exact amount of the fin's offset is not known, it should be offset about 1/2" toward the left, provided the airplane is equipped with a tractor engine of standard (or clockwise) rotation.

After the offsetting device has been locked, the vertical alignment of the front portion of the fin and the level position of the front of the stabilizer can be adjusted in a manner similar to that described above. The alignment of strut-braced tail groups is substantially the same as that of the wire-braced type.

The rigging of the tail is completed by locking all adjustable struts and streamlining and safetying all tie-rods.

RIGGING THE CONTROLS

Rudder - The rudder should be adjusted so that when the rudder pedals are held in a neutral position the plane of the rudder is parallel to the centerline of the ship. The control wires should not be rigged too tightly. It is best to allow about 1/2" of play at the trailing edge of the rudder when the rudder pedals are held rigidly. The control stops which prevent the rudder from coming into contact with the elevators should be properly adjusted, if they are of the adjustable type.

Elevators - Elevator controls should be rigged so that when the control stick, or column, is in a neutral position, the plane of the elevators is level with the ship in flying position. After this adjustment has been made, the action of the elevators should be checked by moving the control stick to the extreme positions. The elevators should have at least as much movement upward as they have downward, usually more. If such is not the case they should be readjusted until the desired movement is obtained. The stops should be adjusted in accordance with the C.A.A. regulations.

Ailerons - Aileron controls should be rigged so that when the stick is held in neutral the trailing edge of each aileron is in line with the trailing edge of the wing. Many of the older types of ships required ailerons to be rigged with droop, or so that the trailing edge of the ailerons was from 1/4" to 1/2" below the trailing edge of the wing when the stick was in neutral. Some modern ships require that the trailing edge of the ailerons be slightly above the trailing edge of the wing. If the exact requirement as to this adjustment is not known, the ailerons should be rigged as first mentioned, namely with their trailing edges even with the trailing edges of the wings. Subsequent adjustments will be suggested by the flight test. Stops should be provided for the ailerons as well as the other controls.

RIGGING
(continued)

PREPARING FOR TEST FLIGHT

After the rigging has been completed the ship should be inspected thoroughly. Every strut should be checked to make sure that it is properly fastened, locked and safetied. Jar the strut by striking it with the hand and immediately investigate any unusual noise or rattle. Inspect every tie-rod to make sure that it is streamlined, properly tightened, and safetied. It is impossible to describe exactly how much tension should be in each wire. They should be firmly taut, yet not tight enough to bow any strut or spar. In general, landing wires should be tighter than flying wires, for they hold the weight of the wings when the ship is on the ground. Large wires are to be rigged tighter than small wires.

Install all vibration dampening brace tubes or sticks, jury struts, inspection plates, etc. Close all slide fastener patches and inspection openings.

Inspect the power plant installation and check all cowling, fairing, exhaust connections, etc.

Check the landing gear assembly, especially wheel bearings and safeties

Inspect the controls for full, free action and for proper action. (Sometimes they are connected backwards by mistake.) Make sure that every bolt is safetied, that every pulley is operating properly and the guard is in place.

As a final precaution, check the rigging visually by standing some distance away and directly in line with the center of the ship. Sight along the upper and lower edges of the wings to make sure that they are in line with the stabilizer.

CORRECTION OF COMMON FAULTS OF RIGGING OR MAINTENANCE

Due to severe maneuvering, bad landings and general wear and tear, a ship may develop faults in flight or taxiing even though it is properly rigged to begin with. A number of these with their remedies are mentioned below.

Noseheaviness is caused either by too little stagger or improper stabilizer setting (on a fixed stabilizer). Increase the stagger by putting the center section ahead or set the leading edge of the stabilizer down. DON'T put a weight in the tail.

Tailheaviness may be due to too much stagger, too much weight toward the rear of the ship (such as extra baggage or equipment aft of the cockpit), dirt and mud in the tailskid opening, or too much negative angle on the stabilizer. Tailheaviness is a dangerous condition, tending to stall the ship and cause a flat spin, so the reason, particularly the weight distribution, should be looked into thoroughly before changing the rigging or tail setting. If the weight distribution is normal, decrease the negative angle on the stabilizer or decrease the stagger by moving the center section back.

RIGGING
(continued)

Wingheaviness may be due to propeller torque or change of alignment after violent acrobatics. Inspect wires and fittings carefully if the latter is believed responsible. Correct by washing in the heavy wing or washing out the other. This is, of course, not possible in a cantilever wing. In this case a small strip of metal about 12" x 4" may be attached near the rear beam at the wing tip with the 12" dimension along the span and the rear edge of the strip bent down about 30°.

Yawing or carrying rudder one way or the other may be due to misalignment of the fuselage. Check as far as possible as described in the preceding pages. If fuselage is in line, offset the fin to the side toward which the ship tends to turn, or lessen the existing offset as the case may be. All changes of this nature should be made a little at a time so as not to carry them too far in the other direction.

Ground looping is a tendency to turn while on the ground, particularly just after landing. It is not ordinarily highly dangerous to the occupants but may be rather tough on the ship as a severe ground loop usually means a broken wing tip, possibly a damaged landing gear, and sometimes a nose-over with consequent disastrous effects on propeller, nose cowling and top wing, not to mention the fin and rudder. And if the ship goes on its back there is always the possibility of fire, due to gasoline spilling on the hot engine. Some of the causes are misalignment of the landing gear, uneven adjustment of shock absorbers, improperly greased wheels, unequal air pressure in the tires, unequal adjustment of the brakes, bent or otherwise damaged tail skid, tail skid shoe on crooked, improper alignment of fuselage. The correction of each of these is obvious. Of course, improper handling of the ship on the part of the pilot may be responsible and this should be determined. Cross wind landings, careless application of brakes, landing with one wing low, are some of the things which adjustments cannot remedy. However, the mechanic should be sure he is not at fault before making any accusations in regard to the pilot.

HANDLING AND MAINTENANCE OF LANDPLANES

The maintenance and repair of the various major units of the airplane are discussed in the sections devoted to the units themselves. However, there are certain things that the mechanic should know which cannot be classified with any specific part of the ship.

To begin with, the plane should be kept clean at all times. Whenever the engine is stopped for more than ten minutes the cowling, windshields, and as much of the remainder of the ship as needs it, should be wiped with a clean rag moistened with gasoline, following with a clean dry rag to give a polish. IF THE ENGINE IS WARM, DO NOT MOVE THE PROPELLER during this cleaning, even if the switch is off, and never move it at any time without checking the position of the switch.

The wiping off of grease and oil should be extended to visiting ships as well as one's own. Nothing so impresses a pilot as to have a mechanic run out as soon as the ship stops on the line and, without being officious and obnoxious about it, start cleaning the ship. If the ship is to be stored or if it needs gas, oil or repairs, the chances are that the pilot will deal with the concern with which the mechanic is located. While wiping off the plane, it is also well to ask the pilot if he wishes the fuel and oil checked, but not to attempt to "high-pressure" him into buying something.

In addition to frequent wiping, ships in regular use should be washed thoroughly with soap and water at least twice a week and more often if necessary. Passengers and students are given a very unfavorable impression if asked to get into a greasy, muddy, or generally disreputable looking "crate". Most aeronautical supply houses carry soaps for washing airplane finishes. Or any good automobile soap may be used. A soft, long-handled brush and a hose are almost essential in order to do a good job. The soapsuds should be washed off thoroughly or the finish is likely to be spotted.

As to the actual handling of the ship, most modern airplanes are equipped with brakes, so that the pilot needs no assistance from the mechanic in maneuvering on the ground. If the plane is not so equipped, the mechanic should either hold back the wing on the side toward which the pilot wishes to turn, or else pick up the tail and carry it around. In picking up the tail, the fuselage should be lifted only at handles, at points marked "Lift", or if there are neither handles nor marks, at the station points where the verticals and diagonals meet the longeron. It should never be lifted by the stabilizer.

If the ship is to be left out over night, it should be turned so that it is facing down wind. It should be thoroughly blocked against rolling, the stick tied forward, the rudder pedals tied fast, and the tail and wings tied to stakes driven into the ground. See instrustions for tying down seaplanes. The cockpit and motor should be covered, and if a real wind comes up during the night, the plane should be watched to see that no harm comes to it.

As to general maintenance, regular inspection should be made as instructed under "INSPECTION". In addition, control hinges,

HANDLING AND MAINTENANCE OF LANDPLANES
(continued)

pulleys and bearings should be oiled frequently, except in the case of ball bearings, which should be washed in gasoline and packed with grease every hundred hours or thereabout. Landing gear wheels should be kept well greased and, needless to say, the brakes properly adjusted. Tire inflation should be checked daily with a pressure gauge. Tail skid shoes should be watched and replaced before they wear through and allow the skid itself to be ground away. Tears in fabric should be patched as soon as they occur. Scratches or worn spots in the finish should be touched up with paint of the proper color. Leather patches for control wires wear through after a time and should be replaced before the fabric is damaged.

Whenever it is possible to avoid it, airplanes should not be left out in the sun. Nothing causes the finish, especially on fabric, to deteriorate as rapidly. When ships must be left out, the engine and cockpit and especially celluloid or pyralin windshields should be covered. Constant exposure to the sun causes windshield material to become yellow and crack so that it quickly loses its transparency. As soon as a windshield becomes cloudy it constitutes a hazard and should be replaced. This is a simple job if the old one is used for a pattern.

INSPECTION

The Civil Air Regulations require that a licensed airplane be inspected every twenty-five hours of flying time, and at least once every seven days prior to flight, by a licensed airman. In addition, a more thorough inspection is required every hundred hours of flying time. The results of the inspection are entered in the log book of the airplane. The items to be inspected are listed in Bulletin No. 7, a copy of which should be in every mechanic's possession. In general, the twenty-five hour inspection covers such items as can be inspected without any disassembly, and the periodic or hundred hour inspection includes also parts which are accessible by removing cowls, inspection plates, fairings, etc. However, there is no limit to the frequency of inspection and the good mechanic goes over the ship at least once a day, if it is being used, and gives it a general "once-over" every time he goes near it. Good inspection reduces maintenance expense, not to mention its need where the safety of the passengers and crew are concerned.

Since every make of airplane differs, the inspection routine also differs. However, the following list, compiled from the daily inspection sheets of several large airlines, is a guide which will cover almost any airplane. By using such a list and checking each item as it is inspected, it is not likely that anything of importance will be overlooked. This list applies only to the airplane. The power plant is discussed in "Aircraft Engine Maintenance."

FUSELAGE
Cowling
Cover
Structure
Cockpit
Windshield
Doors
Windows
Upholstery
Toilet
Chairs
Heaters
Mail Compartment
Flight Controls
Safety Belts
Flares
Flare Release
Pyrenes
Ventilators
Water Tanks

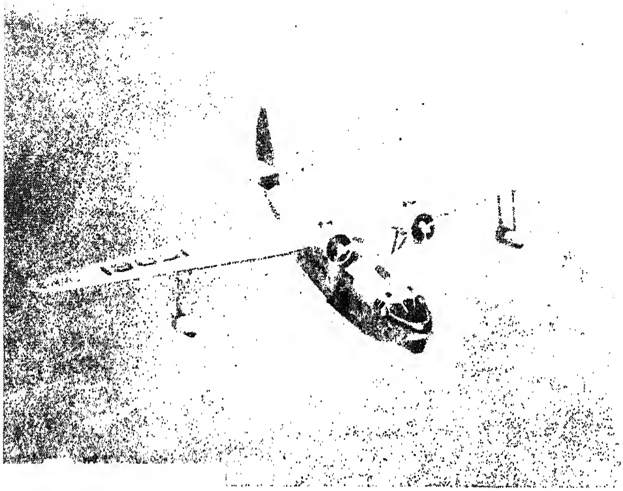
EMPENNAGE
Fin
Stabilizer
Rudder
Elevators
Hinges
Stabilizer Control Mech.

LANDING GEAR
Axles
Struts
Oleo
Wheels
Tires
Brakes
Controls
Liquid
Pressure
Hub Caps
Bearings
Fittings
Retracting Mechanism
Streamlines
Skid Assembly
Shock Cord
Shoe
Oleo
Wheel
Grease

WINGS
Ribs
Spars
Wires
Struts
Spacers
Internal Wires
Covering
Control Cables
Ailerons
Hinges
Bolts
Fittings
Mail Compartment

EQUIPMENT
Emergency Rations
First Aid
Hand Crank
Tool Kit
Cockpit Cover
Engine Cover
Keys
Log Book

HANDLING AND MAINTENANCE OF SEAPLANES



SIKORSKY S-43 AMPHIBIAN FLYING BOAT

TYPES OF WATER AIRCRAFT

The general term "seaplane" is often used to cover all the various types of aircraft which are capable of "landing" on and taking off from water. However, as explained in the pages on "FLOATS AND HULLS", the word seaplane applies strictly to an airplane with floats instead of wheels and the type which uses a boat hull instead of a fuselage is a flying boat. An amphibian is either a seaplane or flying boat equipped with wheels which make it possible to land and take off from land as well as water. Amphibian seaplanes are rare. The most notable example is the Seversky, illustrated herewith, which holds the world's speed record for amphibians. (230 m.p.h.)

Small amphibian boats are, as a rule, rather inefficient as compared with landplanes of the same horsepower, due to the high resistance of the hull in comparison with a fuselage, the added weight, and the resistance of the engine which is usually above the hull. Also, they are more expensive, which keeps down their sales. The advantages of being able to land on either land or water is attractive, however, and sooner or later some designer will produce one which will give the landplanes good competition.

Seaplanes are a little slower than landplanes and slightly heavier. Otherwise, they compare favorably with landplanes and are becoming increasingly popular with private owners, due to the attractiveness of flying over water with no worries about forced landings, the ability to land at any seashore or lake resort, and the cleanliness, safety, and sport of water flying.

One thing which has retarded the development of seaplanes and

HANDLING AND MAINTENANCE OF SEAPLANES (continued)

Courtesy Edo Aircraft Corp.

DOWNTOWN SKYPORT - NEW YORK CITY

boats has been the scarcity of service stations on the water. This condition is rapidly being remedied, however, and ramps and bases are being constructed all over the country. There are several in New York City, both in the East River and the Hudson. Some are illustrated in accompanying pages. Two of these are floating and the outer end can be raised or lowered by filling or emptying the ballast tanks, either of which can be done in less than a minute. If the ship is a seaplane, it is taxied up on the turntable under its own power to the lower part of the turntable. The outer end of the ramp is then raised and the table rotated 90°. The ship is then loaded or unloaded. A further rotation of 90° points the ship toward the water again. The outer end

AERONCA SEAPLANE AT CHAUTAUQUA LAKE

HANDLING AND MAINTENANCE OF SEAPLANES
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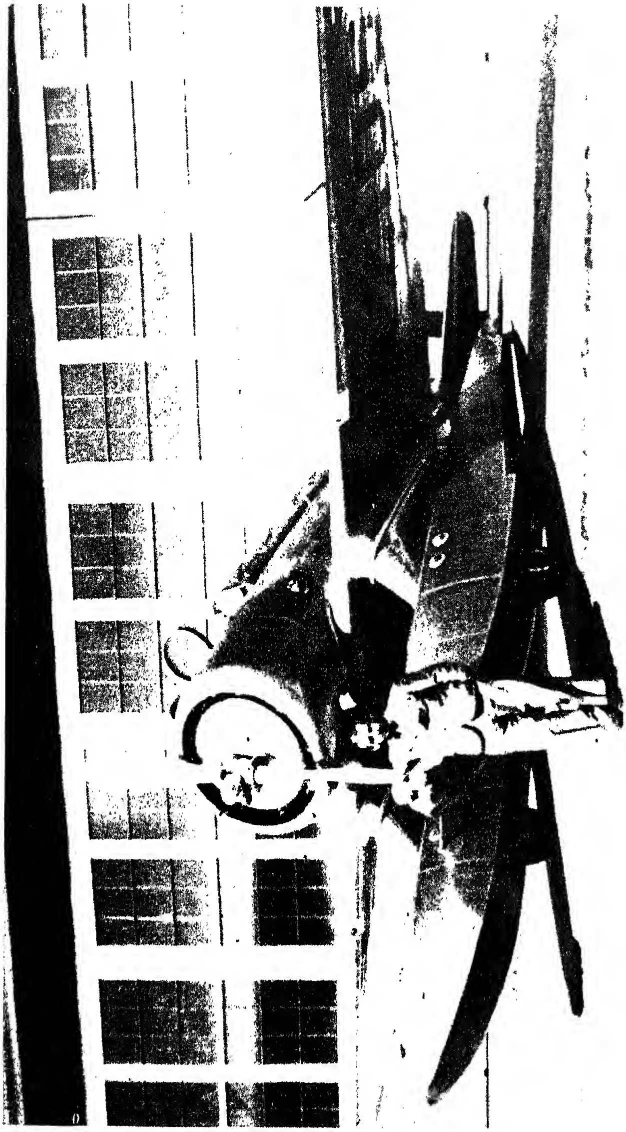
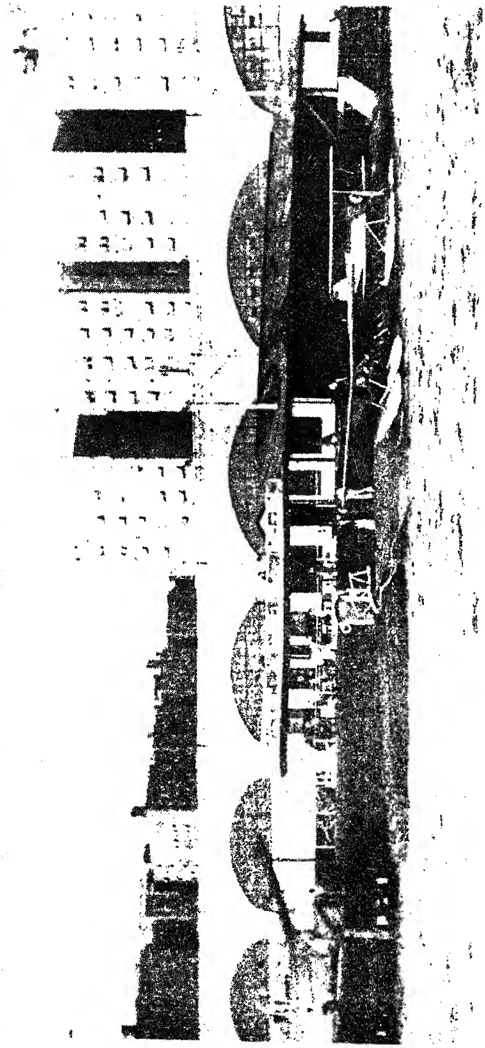


SEVERSKY AMPHIBIAN SEAPLANE

HANDLING AND MAINTENANCE OF SEAPLANES
(continued)



Courtesy Edo Aircraft Corp

SKY HARBOR SEAPLANE TERMINAL - NEW YORK CITY
THIS IS A FLOATING HANGAR BUILT ON A BARGE

of the ramp is lowered and the ship floats off. A side elevation of this ramp is shown in Fig. I and a plan view in Fig. II. If the plane is an amphibian, the wheels are put down and the same procedure followed, except that a mechanic blocks the wheels. The Midtown and Downtown ramps in New York City, illustrated here, are both of this type.

A simpler type of ramp is that shown in Fig. III. A marine railway is extended below the water and a platform with wheels to fit the rails is rolled down so that the ship can taxi onto the platform, after which it is pulled out with a tractor or winch. A similar ramp is shown in Fig. IV without a railway, the platform being mounted on rubber-tired wheels. The simplest arrangement of all is the type of ramp shown in the illustrations of the Aeronca seaplane. The ship is either skidded up under its own power or dragged up backwards with a winch. If the ramp is made of wood and wetted when used, any seaplane of average size will slide up on the keels of the floats if the throttle is opened. It is better, however, to use a platform, or handling wheels. The latter will be explain-

HANDLING AND MAINTENANCE OF SEAPLANES
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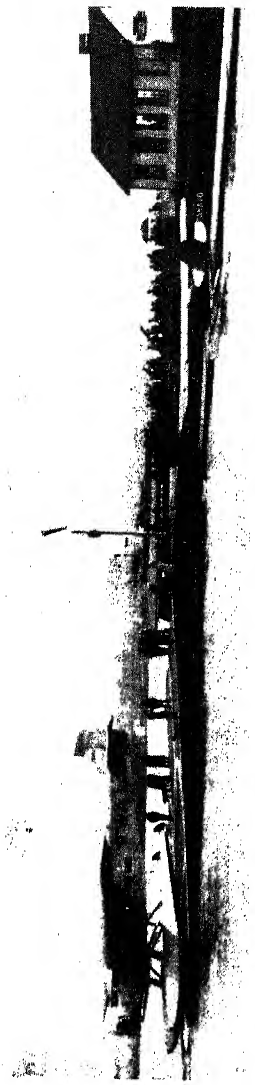

Courtesy Edo Aircraft Corp.

MIDTOWN SKYPORT
NEW YORK CITY

ed later. Fig. V shows a float intended for loading, unloading or tying up temporarily. The ship is not taken out of the water with this arrangement, and it is ideal for picking up passengers and the like, especially where time is important. With a well designed float and an experienced mechanic the load can be taken on without stopping the engine.

HANDLING

While an expert and experienced seaplane pilot can do surprising things in the way of docking a ship without assistance, a good mechanic is a valuable asset. As in everything else, experience is of great importance but there are certain things which can be learned from written instructions.

In the first place, the ramp or float should be kept clear of obstructions and should be inspected frequently to see that there are no nails sticking up. Lines or ropes should be neatly coiled and ready for instant use at all times. A long boathook should be kept handy for when such things are needed there is usually no time to look for them. At least one line should be kept with one end tied to some fixed part of the ramp for if there is a good breeze blowing and the ramp is slippery, a man can easily be dragged off the ramp while attempting to hold a ship which is still in the water. In this connection, a boat or seaplane mechanic should be a good swimmer and should never hesitate to go overboard, summer or winter, if there is any occasion for it. A wetting is not to be compared with a bill of several hundred dollars for repairs to wings or tail surfaces which have been damaged by the ship's drifting into a pier or boat. If the ramp is made of wood, it should be thoroughly wet down with a hose, or with pails of water if no hose is available. Unless the mechanic is accustomed to working with the pilot and knows the latter's

HANDLING AND MAINTENANCE OF SEAPLANES
(continued)

customary procedure, he must be very alert and try to determine, as far as possible, how the pilot intends to approach the ramp or float, whether he plans to skid the ship out of the water or merely ground the floats, or whether he is simply coming alongside - which, of course, is all he can do in the case of a float, under which circumstances the mechanic should be able to figure out the direction of approach.

If the ship is to be skidded up a ramp, the mechanic should stand by to catch the wing on the lee or down-wind side of the ship if the wind is across the ramp, as the ship may try to turn into the wind but never down wind. After catching the wing, he should run along with the ship until it stops, assisting in the steering by pushing on the wing. If the ship does not skid as far as the pilot wants to take it, pulling and pushing on the wing will sometimes help it to slide further. If not, alternately raising and lowering the tail may produce better results. Care should be taken in catching any part of the ship, however, to take hold of parts which are strong enough to withstand the abuse. For example, pushing on the trailing edge of a wing is very likely to break it. The same is true of lifting on the fuselage between station points - or in the middle of a bay, a bay being one section of a truss, from one compression member to the next. Of

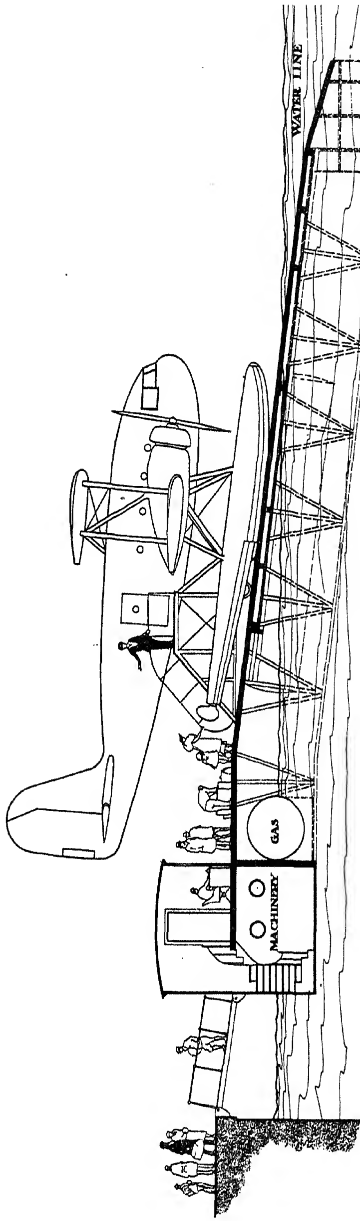

Fig. I

HANDLING AND MAINTENANCE OF SEAPLANES (continued)

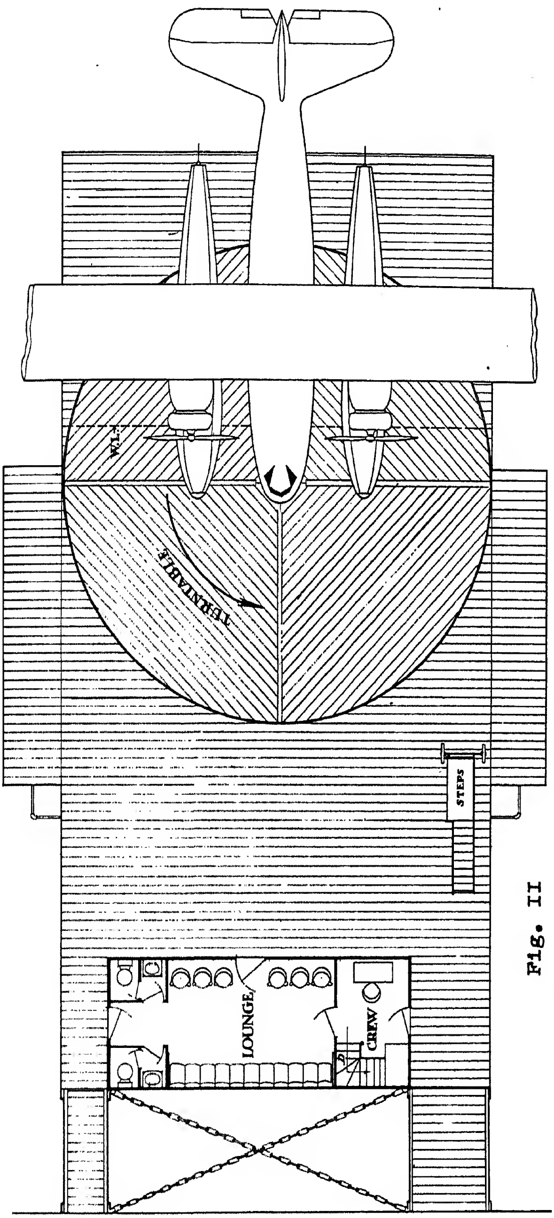

Fig. 11

course, if the ship is an amphibian, the pilot will ordinarily put the wheels down and taxi up the ramp on the wheels. If he has brakes, he needs no assistance, but if not, he needs it much more than a seaplane.

As soon as a seaplane is far enough out of the water to make it practicable, handling wheels should be put on. Large seaplanes often have special "beaching gear", as shown in the picture of the Ford Trimotor. In case no beaching gear is provided, the floats have a hole just ahead of the step, through which an axle may be inserted. Four wheels should be used, one on each side of each float. They can usually be put on by pulling down on the tail of the ship, balancing it on the step, until the stern of the float touches the ramp. This raises the forward part of the float and makes it possible to put the wheels on. The ship is then balanced on the wheels and towed into the hangar. If the ramp is made of concrete, the

HANDLING AND MAINTENANCE OF SEAPLANES
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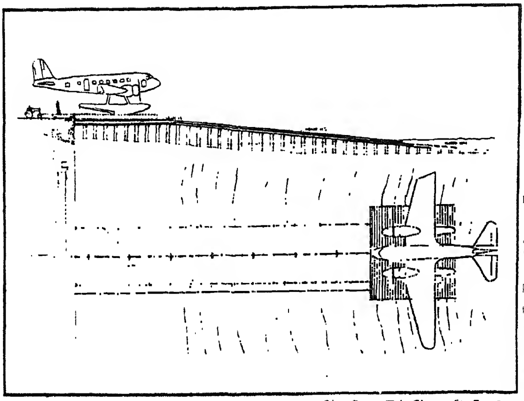
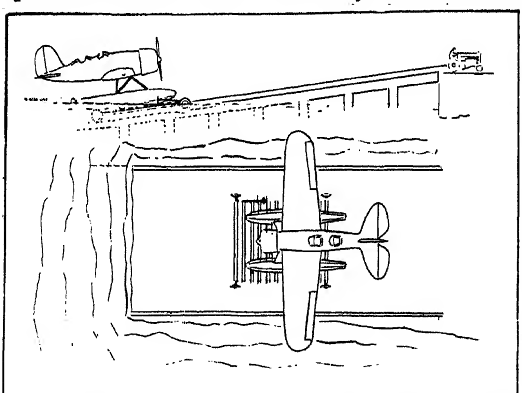


Courtesy Edo Aircraft Corp
III

wheels must be put on while the ship is still in the water. It is possible, but not advisable, to taxi the ship while on the wheels.

If the pilot approaches the ramp in such a way as to indicate that he does not intend to come out of the water, the mechanic should stand by with a heaving line, which is a light line with a padded weight on the end, and a boathook in easy reach. He should catch hold of the first part he can get his hands on and keep the ship from bumping into the ramp. As quickly as possible he should get a line onto some part of the ship, preferably a mooring cleat, to keep it from being blown away. The procedure is the same if the ship is coming into a dock or pier, except that even greater care should be taken to prevent damage, for it is very easy for the wings to swing into a pier. If contact is being made with a float similar to that shown in Fig. V, especially if the approach is made up-wind, there should be no difficulties involved. One great caution should always be observed, however, in all cases. LOOK OUT FOR THE PROPELLER

When there is no ramp, float, or pier available, seaplanes and amphibians are often run in on a beach. If the ship is an amphibian and the beach is hard, the wheels are put down and no difficulty is experienced in taxying out of the water. If equipped only with floats, the ship is brought in until the floats just touch the bottom, particularly if the tide is going out. It may be necessary for the mechanic to wade in and render what help is necessary. In any case, the plane should immediately be turned around, so that the nose points away from shore. In this position, by lifting on



Courtesy Edo Aircraft Corp
Fig. IV

HANDLING AND MAINTENANCE OF SEAPLANES (continued)

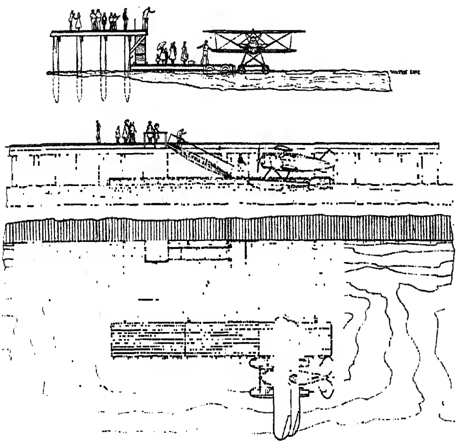


Fig. V

the tail it may usually be pulled far enough ashore so that the passengers can step from the stern of the float onto dry land. Furthermore, when the pilot is ready to taxi out, the ship is already pointing in the right direction. Care should be taken that the tide does not run out and leave the plane high and dry. If this should happen, through the carelessness of the mechanic or the pilot or both, it is possible to get the ship in the water by laying planks crosswise of the intended path. The last few planks are put under the floats by pulling down on the tail and raising the bows. If the planks are wet, the ship will taxi on them quite readily. However, it is much better to keep it afloat in the first place by gradually pushing it out with the tide.

When a seaplane is approaching a ramp, dock or beach at night, never point automobile lights or searchlights toward the ship as they blind the pilot so that it is impossible for him to see where he is going. Direct the lights so that they illuminate the best point of contact. If no lights are available, a small bundle of rags soaked in kerosene or gasoline, put in a tin pan and lighted, make an excellent marker. If lighted before the landing is made, this device also shows the direction of

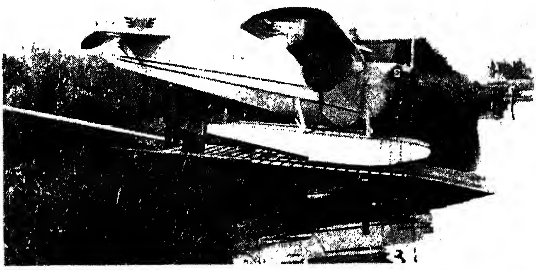
AERONCA SEAPLANE ON RAMP Edo Aircraft Corp

HANDLING AND MAINTENANCE OF SEAPLANES
(continued)

the wind.

TYING DOWN

Tying down a seaplane or flying boat is an art in itself. If the job is done properly, the ship will go through a hurricane without serious damage. The procedure with a flying boat is different from that in the case of a twin-float seaplane only in that boxes or props of some sort are placed under the wing tip floats of a boat or single float seaplane. The twin-float type has no wing tip floats of course.



Edo Aircraft Corp.

AERONCA SEAPLANE ON RAMP

If it is known from which direction the wind will come, point the ship down wind if possible. In any case, tie the stick or wheel in the full-forward position and hard over to one side or the other. Also, tie the rudder pedals. Cover the cockpit and motor if covers are provided. Wedge blocking under the wing-tip floats and under the main float or hull aft of the step. Run double lines in the form of a V, with apex up, from the most solid points available near the end of each wing, the bow and the tail. Then pull the V together with additional line as shown in Fig. VI. This takes all the slack up. Most ships are equipped with tie-down rings near the ends of the wings. If there are none, it may be necessary to fasten to the interplane strut. Care should be taken in this case not to damage the leading edge or ribs. The ends of the tie-down lines should pass through rings set into the ramp or around the boards themselves. If the ship is

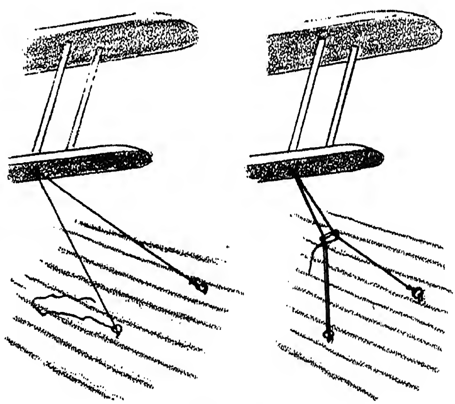
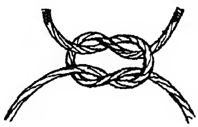


Fig. VI

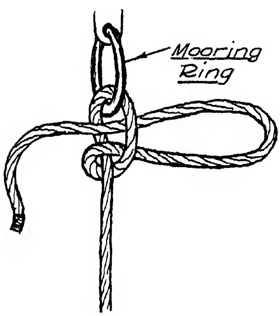
HANDLING AND MAINTENANCE OF SEAPLANES
(continued)

tied down on the beach, it should be dragged above high water mark and stakes driven deep into the ground to tie to. The knot at the first end should be a bowline, a midshipman's hitch or some knot which will not jam. Several of the most useful knots and hitches are shown below.

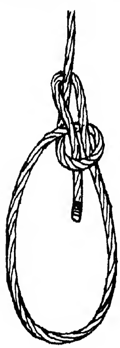
As a further precaution, if it appears that a real blow is likely, it may be well to fill the floats or hull (to the floor boards in the latter) with water. This may mean a tiresome job of pumping later on, but that is much better than having the ship damaged. Most hulls have drain plugs in the bottom, but floats, as a rule, must be pumped out through the hand holes. A good bilge pump is a desirable asset in such case.



SQUARE KNOT



SLIPPERY HITCH



BOWLINE

USEFUL KNOTS

The square knot or reef knot should be used to tie something more or less permanently. It is hard to untie if a load has been put on it. It should not be confused with the Granny, which is similar in appearance but will slip.

For a temporary fastening which can be quickly released, to be used in such cases as tying up a ship while loading or unloading, the slippery hitch, if tied to a small ring and if the loop is left long enough, is unsurpassed. A pull on the loose end releases it, yet leaves the line through the ring with both ends in the hands.

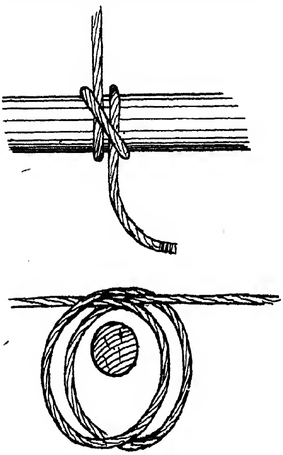
The bowline may be used for permanent or semipermanent fastening, and will never jam.

The clove hitch may be tied around a beam where the end of the beam is not available, or it may be looped in the hands as shown in the lower figure and slipped over the end of a post.

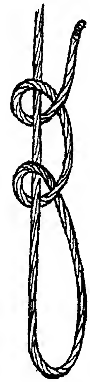
Two half hitches make a fairly secure fastening, but sometimes they jam and become very hard to untie. They should not be used

HANDLING AND MAINTENANCE OF SEAPLANES (continued)

for any fastening which may need to be loosened in a hurry. The timber hitch will not slip easily and makes a good semipermanent attachment if the line is kept taut.

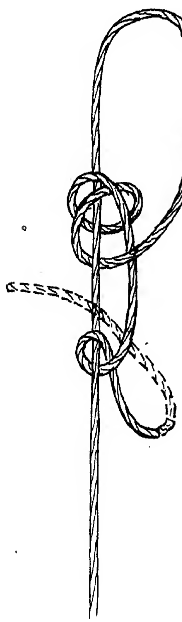


CLOVE HITCH

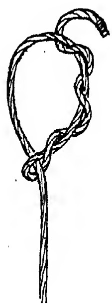


TWO HALF HITCHES

The midshipman's hitch is one of the best, especially if the line is taut while it is being tied. Care must be taken to cross the second loop over the first, or it is almost worthless. Also it is necessary to secure the loose end with a half hitch as shown. This will be easier to tie if a loop is left as indicated by the dotted lines.



MIDSHIPMAN'S HITCH AND HALF HITCH

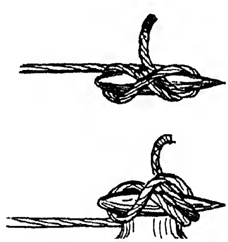


TIMBER HITCH

When fastening to a cleat, a hitch similar to a clove hitch is used. There is no need to worry about this becoming loose.

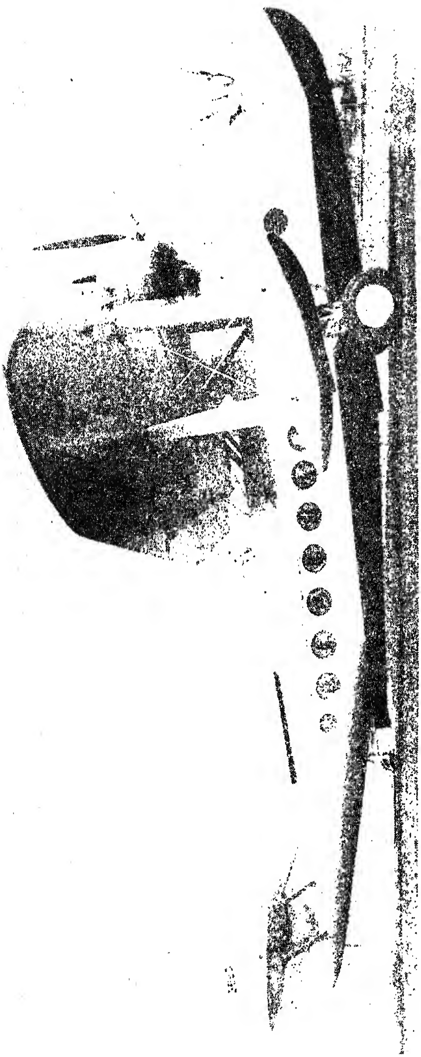
MOORING

It is not advisable to moor a seaplane overnight if it is possible to tie it down on ramp or beach. There may be unsuspected leaks or a storm may come up during the night. However, there is sometimes no ramp nor suitable beach. In such cases, use a regular mooring which has been put down for large boats if possible,



CLOVE HITCH ON CLEAT

HANDLING AND MAINTENANCE OF SEAPLANES
(continued)



Courtesy Sikorsky Aircraft

SIKORSKY S-43 AMPHIBIAN

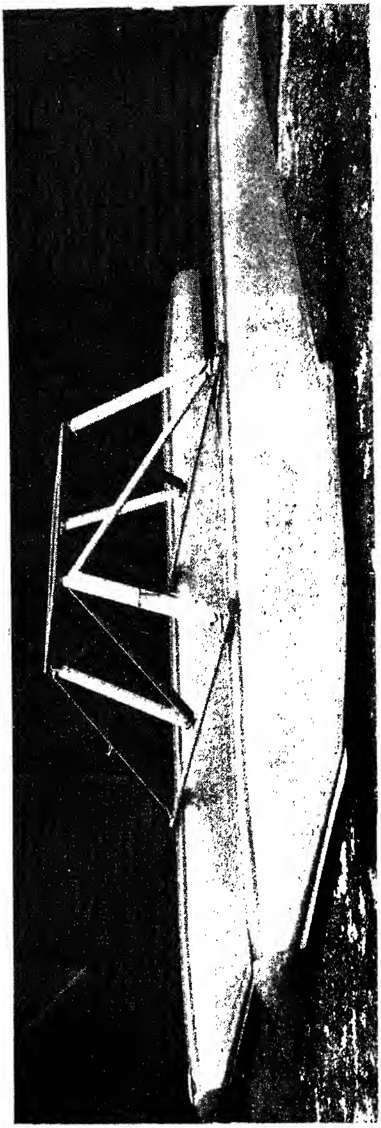
allowing at least twenty feet of line between the mooring float and the plane. An ordinary anchor is very undependable, but if used, the line should be as long as possible.

In attaching the line to a flying boat, fasten to the mooring ring at the bow. In the case of a seaplane, make a bridle by attaching opposite ends of a line to the front float struts or front spreader tube and struts together. This may then be given one turn around the bow cleats on each float. It should extend in front of the floats in the shape of a V, with the point forward. The mooring line is then attached to the point of the V.

If a high wind comes up, it may be necessary for someone to sit in the ship all night, perhaps with the engine running, to prevent the plane taking off and flying at the end of the mooring line like a kite. This tendency to take off may be eliminated by lashing strips of wood about 1" x 3" on edge along the front beam. These are called "spoilers" as they kill the lift of the wings.

If it is possible to moor the ship between two piers a very satisfactory arrangement is to tie the bow to one pier and the tail to the other, or else one wing to each pier. The lines should be long enough to allow for the rise and fall of the tide. Always take advantage of any available protection when mooring, but also remember that the wind may shift and the ship consequently swing around to the other side of the mooring. Hence, space should be allowed for such shifting.

HANDLING AND MAINTENANCE OF SEAPLANES
(continued)



Courtesy Edo Aircraft Corp.

EARLY TYPE EDO FLOATS

TOWING

Flying boats are often equipped with a towing ring somewhere along the forward part of the keel. If such a ring is provided, it should be used. Otherwise, use the mooring ring. In towing a seaplane, a bridle should be rigged as in mooring. Since a boat or seaplane always tends to point its nose into the wind, unusual weather conditions may sometimes make it desirable to tow the ship tail first. There are no definite criteria as to just when this is advisable, but it should be borne in mind as a possibility.

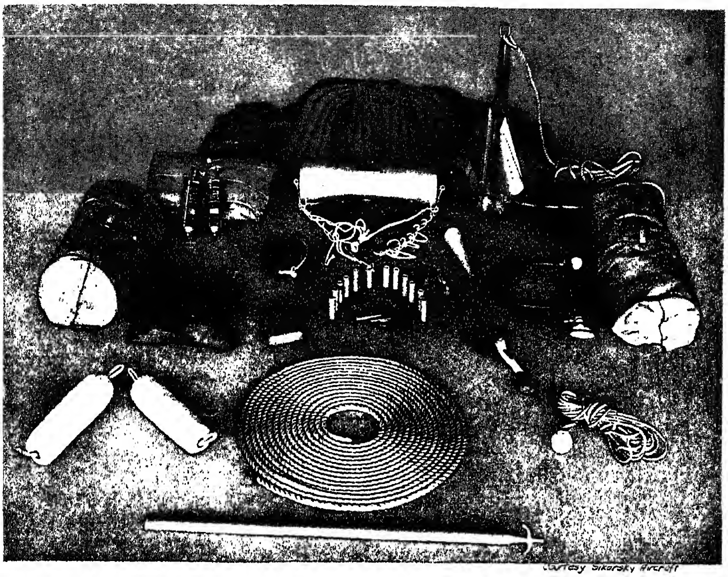
Towing should be done with a small boat rather than a large one, and "the more haste, the less speed." Use as long a line as is convenient, take up the slack gradually and proceed slowly. Otherwise, the line will snap or the towing ring pull out or the plane swamp. Someone should always ride in the plane to keep the tow boat advised as to how things are going.

EQUIPMENT

It is the responsibility of the mechanic to see that the ship is properly equipped at all times. He should familiarize himself with the Civil Air Regulations pertaining to the particular type of plane of which he is taking care, and check the required equipment before each flight. In addition, he should see that such necessary items as mooring lines, a boat hook, a bilge pump, anchor, etc. are on board. Lack of any of these in an emergency may result in serious damage to the seaplane, and even to the passengers and crew. At the very least their absence will cause great inconvenience to the pilot.

An illustration of the equipment carried by the Sikorsky S-43 is shown on the following page.

HANDLING AND MAINTENANCE OF SEAPLANES
(continued)



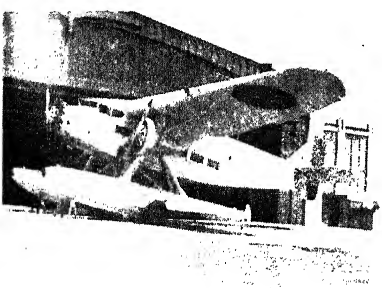
Courtesy Sikorsky Aircraft

EQUIPMENT CARRIED IN SIKORSKY S-43

ASSEMBLY

This refers purely to the change-over from wheels to floats. All the rest of assembly and rigging is the same as on land planes, discussed previously. See "ASSEMBLY AND RIGGING"

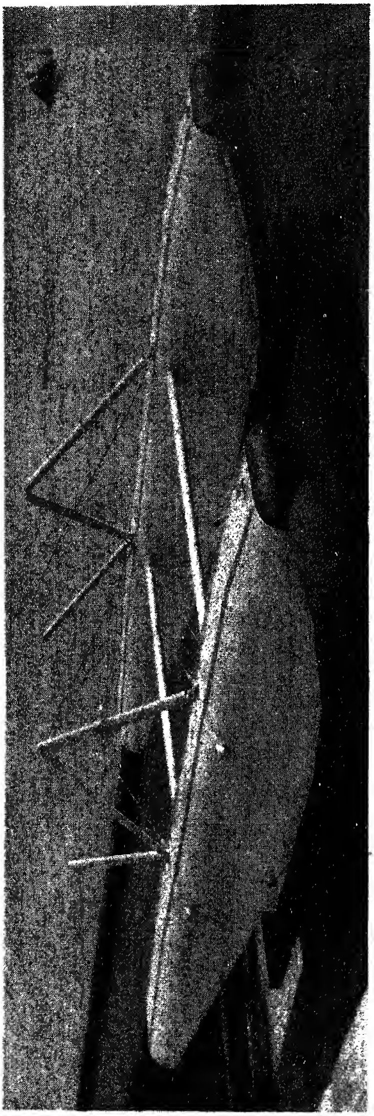
Three types of Edo floats, in the order of their development, are shown on the accompanying pages. The procedure in attaching them to the plane is about the same for all three. The earliest type has the spreader bars mounted on the deck, the next has a round spreader extending into the side and the latest model uses a streamline spreader. Other differences are apparent from examining the illustrations.



FORD TRIMOTOR ON BEACHING GEAR

To replace the wheels on a landplane with floats, put the ship in such a location that a hoist can be hung over the front end of the ship. Put the tail on a tall box or other object so that it is higher than the nose. Attach the hoist with a suitable sling around the crankshaft

HANDLING AND MAINTENANCE OF SEAPLANES
(continued)



LATER TYPE EDO FLOATS

or some other solid point at the front of the ship. Raise ship until wheels are clear of ground, blocking wings to prevent tipping. See that floats are assembled to each other. Remove landing gear, put floats under ship and lower the latter until the float struts can be bolted to the proper fittings. All bolts, pins, fittings, terminals, etc. should be covered with grease ("Rust-Veto" is excellent) prior to assembly. Further instructions as to the use of "Rust-Veto" and similar coatings are given under MAINTENANCE below. Connect struts and wires, tighten, line up floats with centerline of ship and safety all connections. Connect water rudders and align them with air rudders. Ship may now be launched. Two good mechanics should make this change-over on a three - or four - place ship in about half a day.

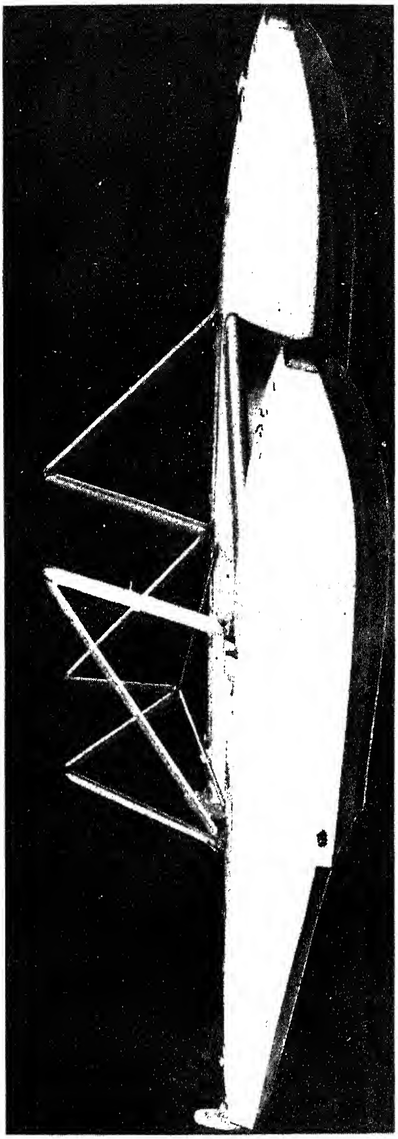
MAINTENANCE

The maintenance of seaplanes involves considerably more than that of landplanes. Also, careless maintenance shows up much more quickly and with more serious consequences, especially if the ship is used in salt water. And since any seaplane, boat or amphibian, is likely to strike salt water sooner or later, the instructions following are given on the basis of salt water operation.

WASHING: As soon as the ship comes out of the water it should be washed down thoroughly with a hose and fresh water. Otherwise, corrosion is much more rapid and in addition the salt leaves unsightly white spots which are much harder to remove once they have dried.

INSPECTION: The floats or hull should be inspected daily for

HANDLING AND MAINTENANCE OF SEAPLANES
(continued)

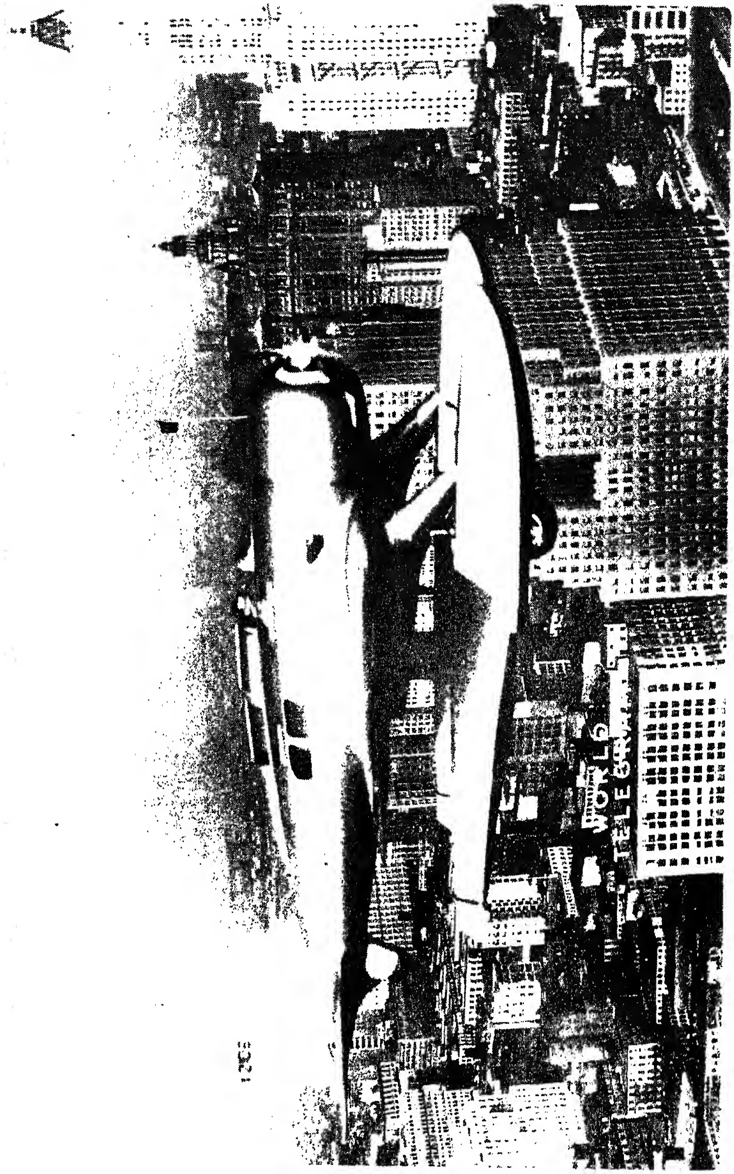


MODERN EDO FLOATS

leaks and loose rivets. Hand hole covers should be left off when the ship is out of the water to allow circulation of air on the interior. A small amount of water may come in through the vent holes in the hand hole covers unless they are kept plugged with soft grease. Never plug them with anything else. Any water should be pumped out with a bilge pump, and when that refuses to draw any more the remainder should be collected with a sponge. The bottom and sides of the floats should be examined for scratches caused by floating debris or by running out on gravel beaches. If any such scratches are found, they should be cleaned and painted. Any whitish powder, especially around rivets, is an indication of corrosion and the area should be carefully cleaned and painted. Instructions on repairs will be found under Metal Work. An excellent material for stopping leaks, temporary patches, etc. is "Plastikon", manufactured by the B. F. Goodrich Co. This material is a sort of rubber cement which is very sticky and never hardens. It should not be used where it is likely to be in contact with gasoline, which tends to dissolve it and wash it away.

GREASING AND OILING: All hinge pins on control surfaces and other moving parts should be oiled frequently, and in addition should be removed frequently for cleaning and inspection. All fittings which are not likely to be brushed against by passengers should be coated with a mixture of melted Rust-Veto and aluminum powder, or melted beeswax and vaseline with aluminum powder. The mixture is applied hot with a brush. When it hardens, it may be smoothed

HANDLING AND MAINTENANCE OF SEAPLANES
(continued)



Courtesy Seversky Aircraft Corp.

SEVERSKY AMPHIBIAN SEAPLANE OVER NEW YORK CITY.

HANDLING AND MAINTENANCE OF SEAPLANES (continued)

out by passing a blow torch flame over it, unless, of course, inflammable material is nearby. Control wires, unless made of stainless steel, should be coiled and soaked in a can of the hot protective compound, which for this use does not need the aluminum powder. All metal parts which are painted should be inspected daily for scratches or wear and if the paint is off, it should be replaced at once. Too much stress cannot be laid on the need for immediate attention to anything of the kind, for it is especially true that in seaplane maintenance "an ounce of prevention is worth a pound of cure". Melted "Rust-Veto" makes an excellent protective coating for any metal parts. It is a good plan to apply it to the inside of the fuselage aft of the cockpit with a spray gun. When used in this manner it should be very hot and thin. It then leaves the gun as a fine mist which settles all over the structure of the ship.

POWER PLANT

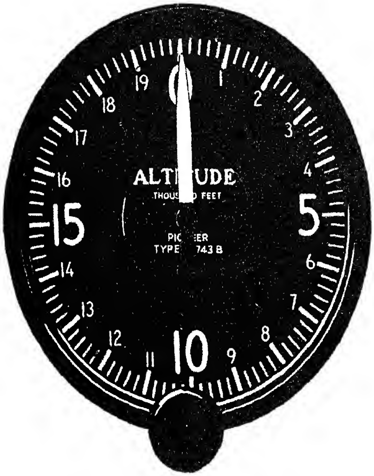
Metal propellers should be kept covered with engine oil and the tips should frequently be rubbed smooth with an oilstone, as they tend to pit rapidly from striking waves. Care should be taken to remove the same amount of material from each blade, however, so as not to affect the balance. Cylinders, especially the lower ones, need to be cleaned and repainted frequently. Exhaust pipes should be metallized. If not, they should be cleaned and painted with exhaust pipe paint at least once a week.

Further information on protection and painting will be found in the sections devoted especially to those subjects.

PUSHER AMPHIBIAN BOAT

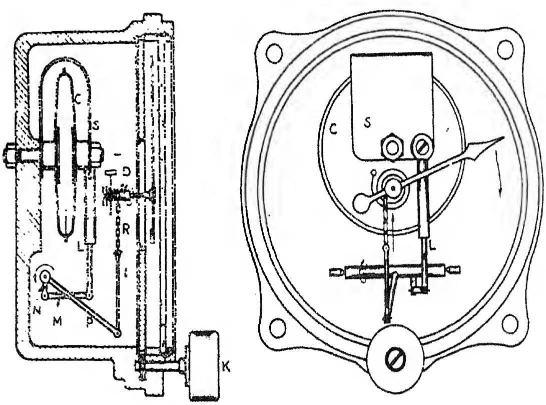
AIRCRAFT INSTRUMENTS

Instruments are becoming increasingly important to flying and new types are constantly being developed. It is not within the province of the field mechanic, however, to make repairs on instruments. The work is delicate and special equipment is needed. Any instrument which is not functioning properly should be sent to the manufacturer or an authorized representative. In the following pages the principles of a number of instruments are explained, not with a view to repair work but because the mechanic's general knowledge should include this information. The illustrations and explanations are supplied through the courtesy of the PIONEER INSTRUMENT COMPANY, one of the real pioneers in the field of instrument design and manufacture.



THE ALTIMETER

"The aircraft altimeter is used for determining the altitude of an aircraft. Essentially, the instrument is similar to an aneroid barometer, refined and more ruggedly constructed for aircraft use, and with the dial graduated in units of altitude instead of pressure. As a result of many experiments, the average relation between altitude and barometric pressure has been determined and figures published by the Bureau of Standards which are used in calibrating all altimeters. The zero of this standard corresponds to a normal barometric pressure of 29.92 inches of mercury. The altimeter is also provided with a dial rotatable by means of the knob K so that any elevation or barometric pressure may be taken as the zero. A barometric scale is frequently provided so that the pilot, when taking off, can set the zero of his instrument to the barometric pressure at the field of destination. The instrument will then read altitude above



ALTIMETER

AIRCRAFT INSTRUMENTS
(continued)

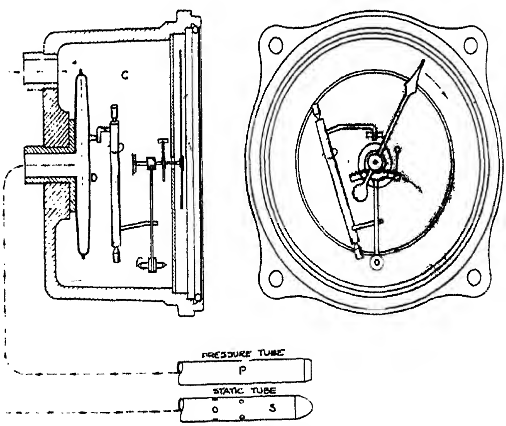
that field.

The heart of the instrument is the diaphragm or cell C which is evacuated and sealed. Normal air pressure will tend to keep the cell contracted with tension on the spring S. As the aircraft climbs, the atmospheric pressure on the cell decreases, allowing the spring to expand the cell. Attached to the spring is the long level L which connects with multiplying links and levers M, N and P as shown, ending with the fine chain R which wraps around the drum D on the hand shaft. A small hairspring keeps the mechanism taut. Thus expansion of the cell is transmitted to the pointer, causing an indication of altitude. Pure nickel chain and jeweled bearings serve to eliminate friction in the mechanism.

All altimeters are subject to changing barometric pressure. This may be used to advantage by observing the position of the hand with respect to the barometric scale and using the instrument as a weather barometer."

THE AIR SPEED INDICATOR

"An Air Speed Indicator is used to show the speed at which an airplane is moving thru the air. Every ship has a certain safe flying range of speed, the lower extreme approaching the stalling point, and the higher extreme approaching a dangerously steep dive. The air speed for a given engine speed is therefore an index of the fore and aft angle of the airplane.



AIR SPEED INDICATOR

An Air Speed Indicator is really a sensitive differential pressure

AIRCRAFT INSTRUMENTS
(continued)

gauge. The pressures which it measures are generated by a pitot-static tube, which is mounted on a wing strut or in some other location upon the airplane where it receives undisturbed air.

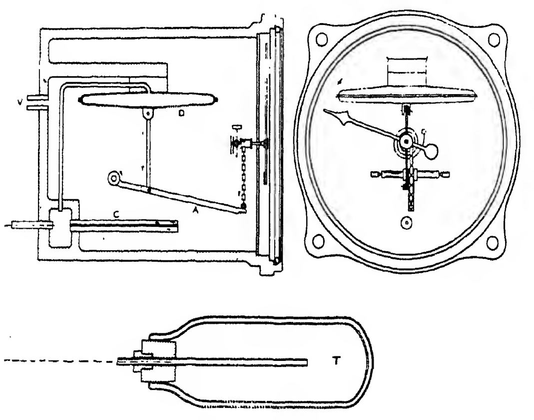
The pitot-static tube consists of two separate tubes, one of which P, is open at the forward end and receives the full impact of the air. The other tube S, is closed at its forward end but has a series of very small holes some distance back from the end. These serve to transmit to the inside of the tube the static pressure in the air at that point, which may be more or less than the static pressure within the fuselage where the indicator is located.

Two lines of tubing connect the pitot-static tube with the instrument. The pitot line connects to the inside of the diaphragm D, and the static line connects to the inside of the case C, which is air-tight. The inside of the diaphragm has pitot pressure and static pressure is outside of the diaphragm. The amount which the diaphragm expands is proportional to the difference between these two pressures. The movement of the diaphragm is transmitted to the hand thru a system of levers and gears as shown on the drawing."

THE CLIMB INDICATOR

"The Climb Indicator shows the rate at which an airplane is climbing or descending. It does not indicate the angle of the airplane with respect to the horizontal, but is operated directly by the rate of change of atmospheric pressure which accompanies changes of altitude. Altho used to measure the actual rate of climb, the primary importance of the instrument is in maintaining level flight under conditions of poor visibility, as in fog, clouds, or at night.

In the instrument is a metal cell or diaphragm D, the outside surface of which is subjected to the barometric pressure of the outside air thru the large vent hole V. The inside of the diaphragm is connected by a tube to the thermally insulated tank T and to the capillary tube C. The latter is a length of glass tube with a very small hole thru the center.

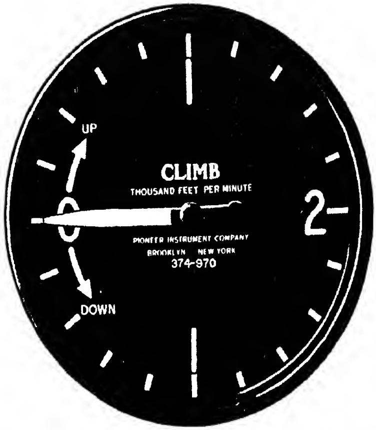


CLIMB INDICATOR

When the instrument is at a given pressure for any time, the same pressure is on the inside as

AIRCRAFT INSTRUMENTS
(continued)

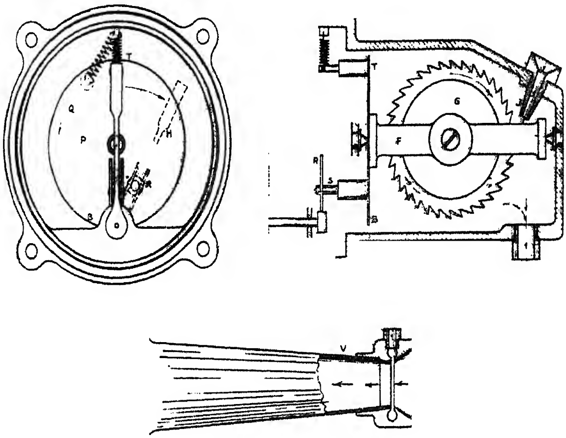
well as the outside of the diaphragm, since the inside of the diaphragm is connected to the outside air by the capillary C. Now suppose the airplane starts to climb. It immediately gets into air of lower pressure. This pressure finds its way at once to the outside of the diaphragm thru the large vent hole V. The air inside the diaphragm, however, is practically at the pressure corresponding to the previous elevation, since the pressure of the volume of air in the diaphragm and tank cannot equalize immediately due to the small size of the capillary hole which connects it to the outside air. As long as the airplane continues to climb, the pressure inside the diaphragm remains higher than that outside because it is not possible to catch up with the outside pressure. The pressure difference which is proportional to rate of climb causes an expansion of the diaphragm and the mechanism is moved as shown by the arrows, so that the hand shows climb. As the plane levels out, the pressures equalize and the hand returns to zero. During descent, similar action takes place, except that the high and low pressures are reversed."



TURN AND BANK INDICATOR

"As the name implies, the Turn and Bank Indicator actually incorporates two instruments in one. The diagrammatic drawing shows only the Turn Indicator. The Bank Indicator is shown and explained in the following illustration and explanation. The Turn Indicator shows when the airplane is making a turn by a movement of the hand from center to the side in which direction the turn is being made. As long as the plane is flying straight the hand will be vertical or on center. A slow turn to the right will cause a small displacement of the hand to the right, a fast turn will bring about considerable hand movement. As soon as a turn is stopped the hand returns to the center position no matter which way the airplane is pointed. The action of the instrument is made possible by the use of a small gyroscope or

wheel which revolves at very high speed (about 10,000 R.P.M.). The gyro marked G in the drawing rotates as shown by the arrow, being driven by the stream of air from the jet J. Air is sucked out of the case by the Venturi tube V which is connected by tubing to the position N. Its axis is carried in the frame F which is mounted on pivots front and rear so that the frame can rotate as shown by the arrow at Q. A round disk or plate P is mounted on the frame at the top of which there is fastened a spring. This spring tends to prevent rotation of the plate and keep the part marked T at the top. The pin S at the bottom of the plate rides between the prongs of a fork R in such a way that the hand rotates in the opposite direction to the plate.



TURN & BANK INDICATOR

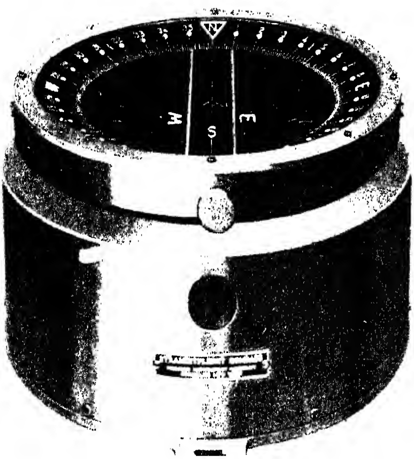
The gyroscope has a peculiar property known as precession which may be briefly explained as follows: Whenever a gyro which is rotating about its axis is forced to turn about some other axis, it will attempt to put itself in such a position that its axis of rotation will line up with the axis about which it is forced to rotate. It will also do this in such a way that the directions of rotation will be the same. In the Turn Indicator the gyro rotates about a lateral axis. It is mounted in a frame which is free to rotate about a fore and aft axis. This latter rotation is opposed by the spring. For example, when the airplane turns to the right, it causes the instrument to be rotated to the right about a vertical axis. The gyro tries to carry its frame around so that the gyro axis will also be vertical. The movement is in the direction of the arrow Q which if completed would leave the gyro wheel rotating the same way that the airplane is turning. The faster the turn, the stronger will be the attempt of the gyro to precess, stretching the spring and bringing about movement of the hand. As soon as the airplane ceases to turn, the gyro no longer tries to precess and the spring will pull the assembly back to the center position."

THE MAGNETIC AIRCRAFT COMPASS

The magnetic aircraft compass consists of a "card" floating in a liquid which damps oscillation. On the card are marked the

INSTRUMENTS
(continued)

four points, North, East, South, and West, with intermediate markings for the degrees between them. North is zero or 360°, East is 90°, etc. The last digit is left off as a rule so that the figures can be made larger without confusion. Thus, "3" is 30° and indicates a course east of North. The white line across the face is called the lubber line and the figure which it crosses indicates the course being flown. The type shown in "A" is mounted on the instrument board, and that shown in "B" is mounted on the floor. The latter is the Pioneer STRAIGHTFLIGHT compass and has a movable lubber line which can be set to the desired course. The pilot then directs the plane so that corresponding lines on the card remain parallel to the lubber line.



One Half Actual Size

"COMPENSATION - To obtain reliable and accurate performance, it is most important that the instrument be installed in a good magnetic location and be properly compensated. It is advisable to have the Compass as far as possible from steel members in the airplane and to keep electrical instruments or electrical wires away from the Compass as far as conditions will permit. Before proceeding with compensation, the Compass should be checked on all headings to see that original deviations do not exceed 30 degrees. Changes in deviation with movement of controls should be checked and eliminated. Compensation can then be made, proceeding as follows:

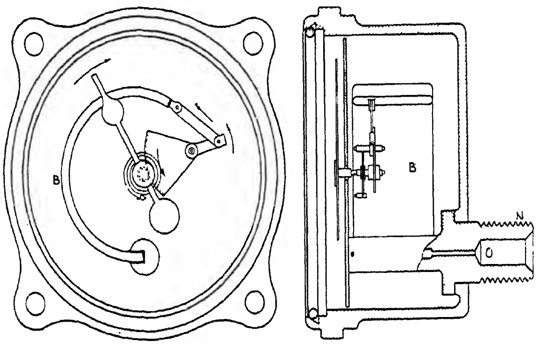
Head the airplane to magnetic North, using a Compass rose or pelorus. Note the reading of the Compass and eliminate the error by inserting magnets in the athwartships compensating chamber. Now head the ship East and once again remove errors present by placing magnets fore-and-aft. The airplane should then be headed South and the error noted. Only

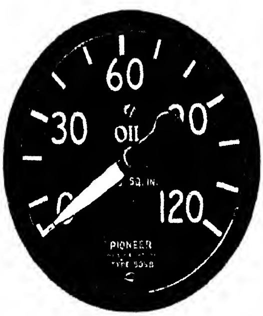
AIRCRAFT INSTRUMENTS
(continued)

half of this error should be taken out by adding or subtracting magnets from the athwartships chamber. Now head the ship West and again remove half the error by adding or subtracting magnets. The Compass is now compensated and the ship should be swung on successive headings at 30 degree intervals, noting the reading of the instrument on the correction card."

THE PRESSURE GAUGE

"Pressure gauges have several uses on an airplane. All machines carry an oil pressure gauge to measure the pressure at which lubricating oil is being pumped to the various bearings of the engine. When fuel is pumped to the engine under pressure, feed pressure is measured. Still others measure the pressure in an oleo landing gear or of the air in a starter supply tank. The gauge used in each case is the same construction, the only difference being in the range and dial employed.





Type 505B

A tube is led from the point where pressure is to be measured to the connection N at the back of the gauge case. The pressure is transmitted thru the hole O to the inside of the Bourdon tube B.

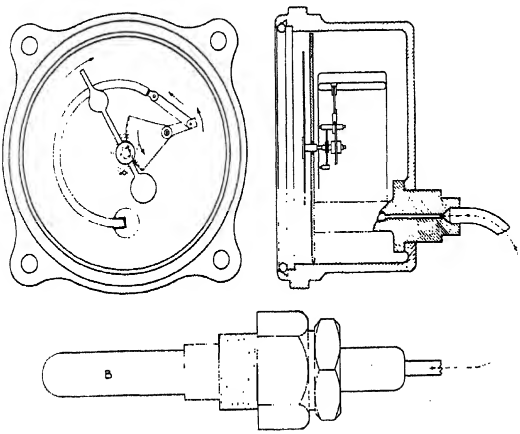
The Bourdon tube is made of spring tempered brass or bronze tubing which has an elliptical cross section and is sealed at the end. It has the characteristic of attempting to straighten out when internal pressure is applied. The tube returns to its normal position when the pressure is released. The movement of the tube, which is proportional to the amount of pressure applied, causes a movement of the links, levers, and gears, as shown by the arrows on the drawing, causing the hand to indicate the pressure."

THE THERMOMETER (Vapor Type)

"Temperature Gauges, or Thermometers are used in aircraft to measure oil or water temperatures in aircraft engines. Two types

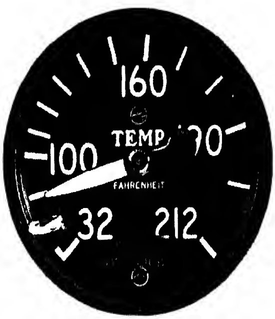
AIRCRAFT INSTRUMENTS
(continued)

are in general use, the liquid and vapor, the vapor type being most commonly used. This consists of an indicating instrument connected by a small soft metal tube B which is placed in the oil or water, the temperature of which is to be measured.



TEMPERATURE GAGE

The bulb B is partly filled with a highly volatile, non-freezing liquid. As the temperature at the bulb increases, the liquid volatilizes and creates a pressure in the tubing which is transmitted to the instrument. The indicating instrument is a conventional pressure gauge such as illustrated on preceding page, except that the dial is graduated in degrees of heat instead of pressure. As the temperature at the bulb B increases, the pressure created by the volatilized liquid is transmitted thru the connecting tubing to the indicator on which is shown the temperature of the liquid which is to be measured."



Type 506B

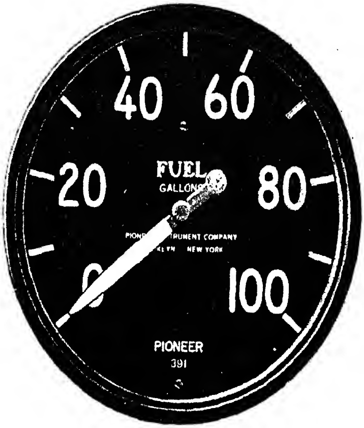
THE HYDROSTATIC FUEL LEVEL GAUGE

"The operation of a Hydrostatic Fuel Level Gauge depends upon the fact that the pressure at the bottom of a tank containing liquid is proportional to the height of liquid.

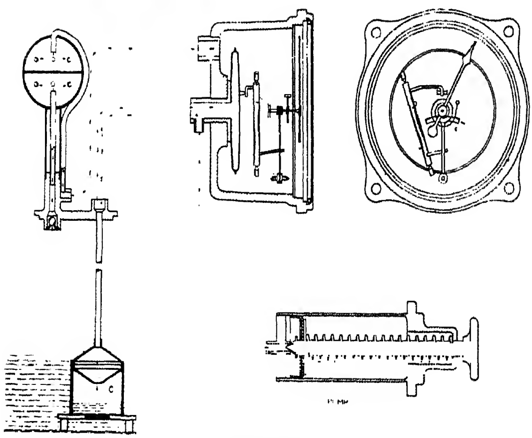
At the bottom of the gasoline tank, a cell C is mounted which serves as a measuring point for this pressure. The bottom of the cell is connected by small holes to the interior of the tank. The top of the cell is connected by a tube line to the inside of the diaphragm of a differential pressure gauge. A small pump is connected into this tube line between the diaphragm and the cell. The other connection at the top of the gauge is carried to the point at which the tank is vented, so that the pressure within the gauge case, on the outside of the diaphragm, may be the same as the pressure in the top of the fuel tank above the liquid.

AIRCRAFT INSTRUMENTS
(continued)

When the gauge is first installed, the tube above the cell C will, of course, be full of liquid up to the liquid level in the tank. The pump is therefore operated, and as air is forced into the line the liquid is blown out until the cell C is full of air. The pressure which it is necessary to maintain on this air is proportional to the depth of liquid, and as this pressure is transmitted directly to the inside of the diaphragm, the diaphragm expands a corresponding amount. Operating thru the links and levers in the directions of the arrows on the drawing, the hand is caused to assume a position which shows the amount of fuel.



Changes in air pressure, due to changes in elevation or in temperature, cause the loss of small quantities of air from the cell C. This may be replaced at any time by operating the pump. The gauge continuously shows the amount of fuel, subject to the errors caused by the slight loss of air. The exact reading may be obtained at any time by operation of the pump, altho this is only necessary at infrequent intervals."



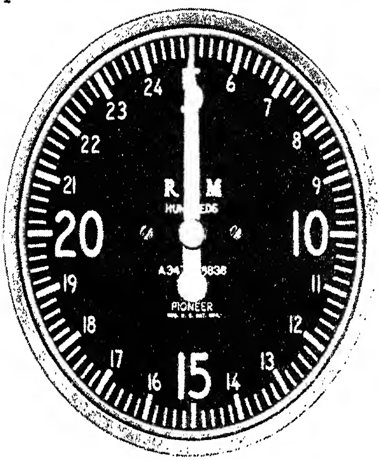
FUEL LEVEL GAGE

THE TACHOMETER

"The tachometer indicates the speed of rotation of the airplane engine. The indications are expressed in revolutions

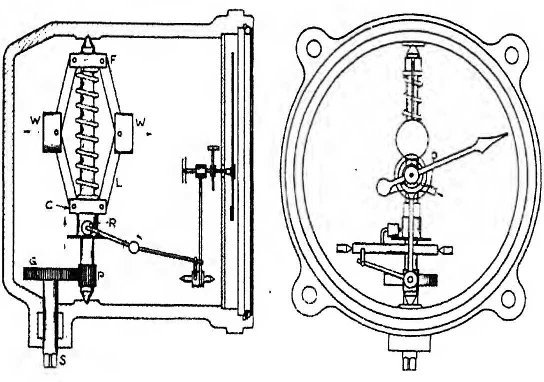
AIRCRAFT INSTRUMENTS
(continued)

per minute (R.P.M.). The tachometer is of utmost importance on an aircraft, being a prime indicator of the condition of the engine. Before taking off, a pilot should always open his throttle fully and note the maximum R.P.M. of his engine. If it does not come up to the proper speed, he knows that his engine is not delivering its full power. When in the air he throttles his motor down to "cruising" R.P.M. to avoid excessive strain on the motor and to operate at an economical speed.



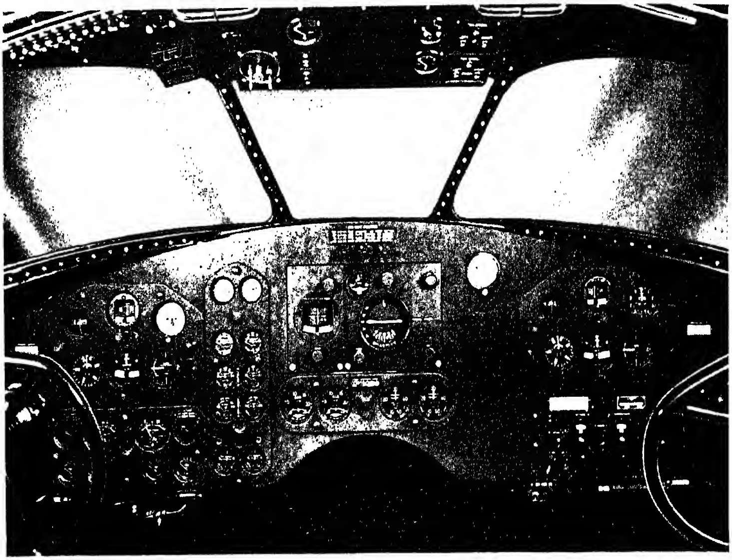
Actual Size

The tachometer shown in the drawing is of the centrifugal type. This is the type most commonly used because of its dependability. Its operation depends on centrifugal force, the intensity of which varies with the speed of rotation. A flexible shaft from the engine is connected at S and directly drives the gear G. This in turn meshes with the pinion P driving the pinion shaft at a higher rate of speed. Flyweights W are mounted on the ends of links L which are also connected to the two collars F and C. The collar F is fixed to the shaft at the top. C slides up and down on the shaft and carries a flange on which rides the roller R. A coil spring tends to hold the collar C down on the shaft. When the pinion shaft is rotating, the weights tend to fly out pulling the collar C up against the coil spring compressing it an amount proportional to the speed of rotation and moving the roller R accordingly. This moves the rest of the mechanism as shown by the arrows, causing the hand to indicate R.P.M. A hairspring keeps the mechanism under slight tension and prevents fluctuation of the pointer."



TACHOMETER

AIRCRAFT INSTRUMENTS
(continued)



PILOT'S COMPARTMENT WITH INSTRUMENTS
AND CONTROLS ABOVE AND BELOW THE WINDSHIELD

INSTRUMENT EQUIPMENT
IN SIKORSKY S-43

WINDSHIELDS AND WINDOWS

Materials from which windshields and windows are made may be divided, roughly into two classifications, flexible and rigid. Examples of the flexible material are Pyralin and Plastacele, while safety glass is an example of the rigid type. The first two are used almost exclusively for open cockpit ships and small cabin airplanes. Plexiglas and safety glass are used chiefly on larger planes.

Pyralin - This is a transparent plastic similar to cellophane and may be purchased in standard sheets or half sheets. The standard sheets measure 21" x 50", and range in thickness from .030" to .150". Other sizes may be obtained on special order. New Pyralin is comparatively tough and may be bent easily in a single curve if the radius of the curve is not too small. It may be formed into a double curve by first soaking it in hot water and gradually bending over wood forms. However, such a procedure is not recommended for, as a rule, some of the transparency is lost during the heating and bending process. As the Pyralin ages it becomes more brittle and consequently will crack more readily, especially if it is under any internal strain, such as would be induced by a double bend.

Pyralin has a tendency to discolor with age, becoming opaque and yellowish. Constant exposure to sunlight will hasten discoloration and for this reason new windshields should always be shaded when not in use. If it is impossible for the airplane to be kept in the shade the Pyralin should be covered with some material to protect it from the direct rays of the sun. If convenient, an air space of at least one inch should be kept between the Pyralin and the covering material.

Being of a cellulose base, Pyralin is an inflammable material and should be treated as such. No material that has the slightest abrasive quality should be used to clean Pyralin, as the polished surface will be destroyed and the transparency impaired. Great precautions should be taken to prevent paint and especially lacquer or dope, from getting on Pyralin, as the surface polish will be destroyed in an attempt to remove the foreign matter.

Plastacele - Plastacele is an improved material similar to Pyralin and in general has the same characteristics. However, it will not discolor or crack as readily and in addition has the tremendous advantage of being non-inflammable. For these reasons, Plastacele is being used widely by the manufacturers of military planes. At present Plastacele costs about 13% more than Pyralin.

Plexiglas - This is the trade name of an exceedingly popular windshield material manufactured by the Rohm & Haas Co. Inc., of Philadelphia, Pa. It is a thermoplastic of high transparency (having a light transmission of 91 - 92%, or slightly higher than plate glass). It may be obtained in unusually large flat sheets ranging in thickness from .060" to 1/2". The manufacturer also supplies Plexiglas in single and double curves for formed windshields, landing light covers, gun turrets, cockpit enclosures, etc. For special uses it may be obtained in rods and square bars.

New Plexiglas has a surface polish which cannot be duplicated

by the mechanic. For this reason extreme care should be taken not to scratch the surface. Obviously no abrasive material should be used when cleaning. Likewise, no substance that is a solvent for Plexiglas should be used. This includes esters, ketones, aromatic hydrocarbons and chlorinated hydrocarbons.

Plexiglas may be cleaned with kerosene or naphtha, using a soft cloth that is free from grit and dirt which might scratch the surface. Window sprays should never be used as a cleaner, for many of them contain solvents for Plexiglas. A water solution of Dreft or Drene is highly recommended for washing Plexiglas. Dreft or Drene (which may be purchased at drug or departments stores) is dissolved in water, forming a soapy solution. Use a soft cloth to wash the surface, rinse with clear water and dry. Household cleaning powders must not be used, since they contain abrasives which are injurious to Plexiglas. The only recommended method of brightening the surface of Plexiglas is by polishing, as described on the following pages. Never use solvents such as acetone, ethyl acetate, benzene, ethylene, dichloride, etc., for these solvents soften the surface.

From such an imposing array of precautions to be observed in cleaning, it might seem that Plexiglas is a particularly delicate material, however such is not the case. If given proper care it will probably last the life of the airplane for it is only very slightly affected by age, light, acids or alkalies (except by strong oxidizing acids).

Safety Glass - Safety glass is made by cementing a sheet of transparent plastic similar to Pyralin, between two sheets of ordinary window, or plate glass. Safety glass of this type is not bullet proof nor unbreakable, but it is shatterproof. This is an important feature for, as everyone knows, bits of flying glass can be extremely dangerous. Sometimes safety glass is made of more than three plies, however an uneven number is always used so that the outside plies can both be glass. It is supplied in standard flat sheets ranging in thickness from 1/8" to 1/2".

Very little need be said about the care and cleaning of safety glass for it should be treated as ordinary glass. It is recommended that some type of window spray or a soap solution be used for cleaning in preference to solvents or gasoline as the latter may run into the frame and attack the inside laminations or the sealing compounds and tapes. Some types of safety glass have a tendency to discolor with age and light, therefore it should not be exposed unnecessarily to the direct rays of the sun.

REPLACING FLEXIBLE WINDSHIELDS AND WINDOWS

When Pyralin or Plastacele windshields or windows become sufficiently discolored as to impair their transparency it is time for them to be replaced. For not only is the vision restricted, but the material has become brittle and may possibly crack or break in the air. Obviously, the first thing to do is to remove the old Pyralin; however, if it is a frameless windshield, such as in Fig. I-A, that is being replaced, and if there seems to be any possibility of the material breaking when being removed, it is sometimes advisable to

WINDSHIELDS AND
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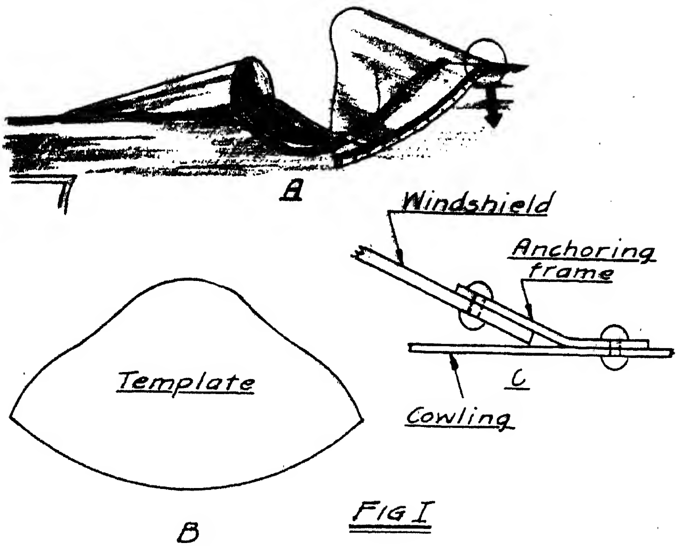

FIG I

make a paper template (Fig. I-B) which exactly fits the windshield so that if the material does break, the template may be used to trace the outline for the replacement. A template should also be made before removing the windshield from a semi-rigid frame.

Many times flexible windshields are fastened to frames, as shown in the detail drawing in Fig. I-C. Soft aluminum rivets are usually used as fasteners, but in some cases machine screws are employed. If rivets are used they should be removed by drilling the head off and punching out the remainder. It is seldom that a "rivet buster" chisel can be used for the frame is made of such light gage material that it will bend out of shape easily. In many cases it is easier to remove the frame from the cowling before removing the windshield from the frame. This may have to be done in any case, for some installations make it impossible to rivet the windshield to the frame while the frame is on the cowling.

If the frame is to be removed from the cowling, great care should be taken not to exert too much pressure when drilling the rivets or when loosening the screws, as the cowl will be pushed out of shape. Before actually taking the frame off the cowling it is advisable, if the frame and cowl were painted as a unit, to run a knife point around the outside edge of the frame exerting only sufficient pressure to cut the paint film. If this precaution is not observed, small pieces of paint may be peeled from the cowling, necessitating a touch-up or refinishing job which might have been avoided. Naturally the windshield or window should be removed from the frame in one piece if possible so that it may be used as a template.

WINDSHIELDS AND WINDOWS
(continued)

Either Pyralin or Plastacele may be worked readily with ordinary tools, however great care should be taken not to scratch the polished surface. When tracing the shape of a template on new material a sharp scriber or ice pick should be used. The template should be clamped to the material so there will be no danger of slipping. Two or three small "C" clamps should be sufficient but heavy cardboard or thin plywood should be placed between the clamp jaw and the new material to prevent scratching or denting. Thin Pyralin, up to .030", may be cut with tin snips very satisfactorily; however, material which is thicker than this should not be cut with snips or shears as it has a tendency to crack near the edges. Heavy material is best cut with a coping saw. A hack saw may be used but it is more difficult to cut a sharp curve with this tool.

Edges of Pyralin or Plastacele may be smoothed with a scraper or rough file. It is customary to round the edge slightly in order to remove burrs and loose material.

An ordinary metal twist drill may be used for drilling holes provided too much pressure is not used. Excessive pressure causes the drill to grab in the soft material. No lubrication is required.

If a curved windshield is being replaced it is not advisable to drill all of the holes in the replacement material from the template nor is it advisable to fasten the new windshield to the frame before the frame is adjusted to the curve it will have to assume. A better procedure is to drill the middle hole in the lower edge of the new windshield using the template as a guide. Now fasten it to the frame temporarily using a machine screw. Next, fasten the frame temporaril to the cowl with a few machine screws. Force the windshield to correct position and mark or drill the other holes. Using this procedure there will be no possibility of the frame kinking or the holes not aligning, when it is assembled permanently.

As previously mentioned, the windshields may be fastened to the frame by soft aluminum rivets, with or without using washers, although the latter method is preferable. Corrosion resistant machine screws are also used for frame fastenings and are preferred by many. If such fastenings are used, some method must be provided to safety them so that they will not loosen under vibration.

Pyralin and Plastacele windows and cabin enclosures are used to a considerable extent on light planes. In many cases, the installation is made in the same manner as windshields and the instructions above are applicable. In other cases the material is installed so that it will be flush with the covering. This, of course, necessitates a recessed frame and the material is fastened either by machine or wood screws, depending upon whether the backing is of metal or wood. The seam between the window and the fabric is covered with wing tape, the tape being doped to the cover and also to the Pyralin. If such a procedure is followed, some method must be provided to prevent dope from getting on that part of the Pyralin which is not to be covered with tape, for dope is a solvent which will destroy the surface of this material, thus reducing the transparency. The

WINDSHIELDS AND WINDOWS
(continued)

safest method of protecting the Pyralin is to mask the entire surface except that which is to be covered with tape.

CARE OF PLEXIGLAS

As Plexiglas is a plastic material it may be readily cut, drilled, or formed. However, since it is so essential to avoid scratches it is suggested that the new material be masked on both sides before being fabricated or handled excessively. One of the simplest methods of effectively masking Plexiglas is to paste a sheet of porous paper over both sides. Ordinary gelatin dissolved in water to the consistency of a thick paste may be used in pasting the paper on the surface. Care should be taken, however, not to slide the paper over the surface during the pasting process. Plexiglas masked in this manner should be allowed to remain at least 8 or 10 hours before handling in order to permit the gelatin to dry. A pressure sensitive rubber adhesive may be used for masking purposes in place of gelatin. Materials of this type may be secured from either the Alden Rubber Co. of Philadelphia, Pa., or the Maskite Corp. of Los Angeles, Cal. In any case the masking should be allowed to remain on the Plexiglas during any cutting and drilling process.

Polishing Plexiglas - Small scratches in the surface of Plexiglas may be removed by hand polishing, although it is impossible to regain the original high lustre. Any good automobile cleaner and polish may be used as polishing compounds. A magnesium carbonate which can be procured from drug or chemical stores may also be used if it is first made into a water paste of the consistency of thin cream. If the latter polishing compound is used it should be allowed to stand for a few minutes after mixing and then decanted into a clean vessel, leaving behind all the coarse and undissolved particles. Polishing cloths should be clean, soft and grit-free. Birdseye cloth diapers or outing flannel are highly satisfactory. New cloths should be washed with soap and clean water, rinsed thoroughly and allowed to dry in a dust-free room before using.

The following procedure is recommended for the hand polishing of Plexiglas: Wash the Plexiglas carefully so that no gritty material adheres to the surface. A mild soap solution may be rubbed on the surface with the hands while spraying on a film of water. Note: All steps in the polishing operation should be carried out in the same direction so that any accidental scratches will be less noticeable. The cleaner is applied with a soft, damp cloth and only the scratched area is rubbed vigorously. Caution must be taken not to rub in one place for any length of time, as friction will heat the Plexiglas and cause ridges. The surface should be flushed with clear water frequently to note the condition of the scratches, as unnecessary polishing should be avoided. After the scratches are removed, or considerably improved, all traces of the cleaner should be removed and the surface polished. One of the most effective polishes for this purpose is Simonize wax polish, however any good wax polish may be used. Polish is best applied using about half a yard of soft cloth which has been dampened and folded into a pad to fit the hand. Apply the polish to the surface evenly and thoroughly. After it has dried a few seconds rub lightly with a dry, soft cloth.

"AN" SPECIFICATIONS

In all factories doing work for the United States Government, and in many engaged purely in the manufacture of commercial aircraft, standard parts such as bolts, rivets, turnbuckles, etc. are given numbers to simplify the reference data and drawing notes. As many of these parts must meet Army and Navy Specifications the symbol AN preceding the number is used to indicate such conformity. Space does not permit a complete list of these parts, but the tables following give those in most common use.

The AN number given each part describes the part and gives it its dimensions. For example, "AN6" indicates an aircraft bolt, the diameter of which is 6/16" or 3/8". The length of the bolt is shown by a "dash" number. Thus "AN6-7" means a 3/8" bolt, 7/8" long. Likewise "AN7-12" means a bolt 7/16" in diameter and 1-1/4" (1-2/8") long. A typical rivet designation would be "AN425D4-3", which means a countersunk head rivet, type D (which is 17S aluminum alloy), 1/8" (4/32") in diameter and 3/16" long. On specification numbers which apply to copper and iron rivets, the number followed by "C" indicates copper rivets; if no letter is used, an iron rivet is referred to. Thus "AN435-3-5" means a round-head iron rivet, 3/32" in diameter and 5/16" long; while "AN435C-3-5" means a copper rivet of the same size and shape. The letter "S" is used only in referring to short turnbuckles.

INDEX TO GROUP SPECIFICATIONS

BOLTS

Bolts-Hex.Hd.Aircraft,Drilled for Cotter . .	AN3 to AN16 incl.
Bolts - Clevis	AN23 to AN36 incl.
Bolts - Eye for Pin.	AN42 to AN49 incl.
Bolts - Aircraft, Drilled Head	AN73 to AN81 incl.

CABLE FITTINGS

Thimble - Wire Cable	AN100
Shackle - Cable	AN115
Turnbuckle Assem. - Cable Eye & Fork	AN130
Turnbuckle Assem. - Cable Eye & Pin Eye.	AN135
Turnbuckle Assem. - Cable Eyes	AN140
Barrel - Turnbuckle.	AN155
Fork - Turnbuckle.	AN160
Eye - Turnbuckle, for Pin.	AN165
Eye - Turnbuckle Cable	AN170
Pulley - Control	AN210

FABRIC ACCESSORIES

Fastener - Cowl - Post Type.	AN226
Grommets - Plain & Spur - With Washers	AN230
Eyelets - Lacing	AN240

GROMMETS

Grommet - Rubber	AN931
Grommets - Plain & Spur - With Washers	AN230

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